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THE ECONOMICS OF CLEAN WATER. VOLUME II. ANIMAL WASTES PROFILE

Federal Water Pollution Control Administration
Washington, D.C.

March 1970

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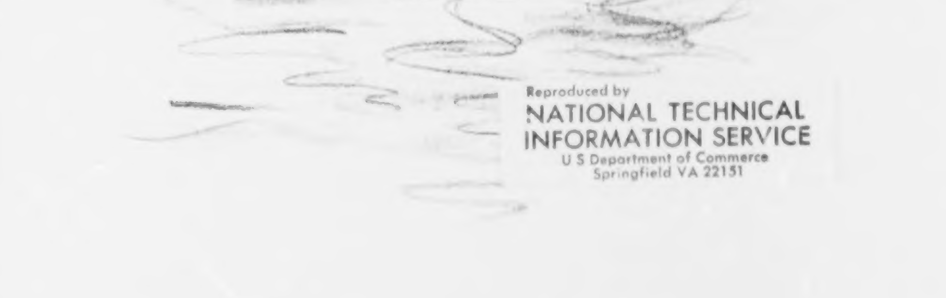
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

THE ECONOMICS OF CLEAN WATER

U. S. DEPARTMENT OF THE INTERIOR



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CLEAN
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THE ECONOMICS OF
CLEAN WATER

VOLUME II
Animal Wastes Profile

MARCH 3, 1849

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this document may be better
studied on microfiche.

U. S. Department of the Interior
Federal Water Pollution Control Administration
March 1970

I

March 3, 1849

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

APR 3 1970

Dear Mr. President:

I am transmitting to the Congress the third report on the national requirements and cost of water pollution control as required under Section 16 (a) of the Federal Water Pollution Control Act, as amended.

The decade of the 1970's, a decade which will address itself to improving the quality of man's environment, will see great strides toward the effort to abate water pollution. The enclosed report entitled "The Economics of Clean Water" represents our current estimates of the investment levels necessary to attain applicable water quality standards.

This report, along with the two previously submitted, contributes to closing the information gap in terms of the overall magnitude, geographical, and financial dimensions, all of which are essential to the development of national policies and programs directed toward achieving water quality standards in an efficient and effective manner.

The alternatives analyzed in the course of this study, especially those aspects contained in Volume I, presented valuable background for development of proposals on aid to municipal treatment works presented to the Congress in the President's Environmental Message and subsequent legislation.

There are four parts to this year's report. The first is a summary of major findings and conclusions of the analysis. The second, Volume I, contains the details of the analysis. The third, Volume II, is a profile of animal wastes. The fourth and last section, Volume III, is an industrial profile of the inorganic chemicals industry.

Sincerely yours,

Walter J. Hickel

Secretary of the Interior

Hon. Spiro Agnew
President of the Senate
Washington, D. C. 20510

Enclosure

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DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
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Hon. John W. McCormack
Speaker of the House of
  Representatives
Washington, D. C. 20515

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SUMMARY

The total costs associated with controlling water pollution from animal wastes cannot be estimated at this time. However, certain general conclusions can be drawn as to the scope of the problem, possible control measures, and the location of major pollution sources or broad areas of probable pollution from animal wastes.

In many cases animal wastes have proved to be significant pollution sources that resulted in fish kills and extensive damage to the ecology of the streams. Additionally, the wastes handling and disposal methods employed by many enterprises make them probable contributors to water pollution even though the present stream monitoring procedures and networks are not comprehensive enough to pinpoint all such nonpoint discharge sources.

In various efforts to assess the water pollution potential of animal wastes, with the lack of information on the extent of pollution from these sources or on control measures that might be used, many reports have tended to view the problem in its most extreme state. That is, they consider all the animal wastes (regardless of origin or manner of disposition) which means that the population equivalent of that volume of wastes is disproportionately greater than the population of the United States. If such a population equivalent of animal wastes is then multiplied by the treatment costs per person for sanitary wastes, the resulting comparative costs are staggering and misleading.

At the present time, however, there is general agreement that not all of the wastes need to be considered as sources of water pollution. Therefore, it would seem that entirely too much emphasis has been placed on the gross possible costs of controlling water pollution from animal wastes. A more realistic base for use in developing programs for water pollution abatement and control from animal wastes is a series of sub-elements that can be independently assessed to determine their pollution potential, applicable control measures, and total pollution control costs.

The prime advantages of the sub-element approach are: (1) the ability to estimate portions of the total animal wastes pollution control picture over time which is important when resources for assessment are constrained, (2) the opportunity to design specific programs for various portions of the total problem, and (3) the provision of the necessary breakdown of the problem for comparing marginal effectiveness of treating various aspects of the total problem. In any period when resources for correction or control of pollution problems are constrained, it is highly desirable to deal first with those problems that provide the most return for the scarce resources available.

Animal wastes should be broadly subdivided by animal species, not because there is no similarity of problems or control measures but because the regional animal concentrations, future growth, and specific application of control measures vary substantially from species to species. Within each species are additional useful breakdowns that may be utilized for comparative purposes as well as for analytical convenience. For example, the major emphasis in this report is on the fat cattle industry. Within this major breakdown of the animal wastes problem are several subdivisions which cover such items as size, location, and applicable control measures.

Frequency of waste discharge and number of animals or total wastes involved in the discharges are primary criteria for use in categorizing animal wastes problems. Regular or daily discharges, such as those from enterprises using water flushing systems, should be analyzed early in the process of assessing the contribution of animal wastes to water pollution because of their high probability of being sources of water pollution and because of the growing use of flush systems in dairy, poultry, and swine enterprises.

Intermittent wastes discharge sources with high total pollution potential, such as beef feedlots subject to runoff, also deserve early attention when the animal wastes contribution to water pollution is assessed. The discharges from this class are less frequent per individual enterprise but the number of animals, volume of wastes, and the number of enterprises involved significantly increase the water pollution potential.

Specific information relative to actual pollution occurring by local area or region is not available. However, the number of animals in each State during some given time period provides an indication of the relative water pollution potential in each State from various animal sources. For example, the midwestern area, California, and Texas generally have high numbers of all types of animals and particularly of the larger-sized animals with high wastes production per animal. Other areas such as the northeastern and southeastern sections have large numbers of specific animals such as dairy and poultry, respectively.

Common Control Methods for Beef Feedlots

Beef feedlots are known sources of water pollution but the extent and distribution of pollution caused by such feedlots is unknown. Further, the present state of knowledge does not permit an adequate estimation of the numbers of types of control facilities that are needed to control water pollution from feedlots. However, an indication of the size and variability of the control problem may be obtained through a general discussion of the known control methods and their applicability under varying conditions.

Types of pollution control measures utilized by feedlot enterprises vary significantly across the Nation as well as within a specific local area. There is no one best solution for controlling pollution from feedlots although there are solutions that have greatest general applicability to feedlots in similar situations. In fact, it is this general applicability in similar situations which will make possible more realistic future estimations to be made as to the total costs of controlling pollution from animal feedlots.

Control measures range widely in complexity and cost. Minimal control measures, in terms of cost and complexity, are water diversion systems that divert drainage water around the feedlots, changes in the drainage route of runoff from feedlots, and, possibly, changes in lot locations to minimize drainage water moving across the lot or to prevent direct drainage from the lot to a watercourse. Other changes in operations such as increasing animal concentrations or adjusting feeding cycles to meet changing climatic conditions can also be used to reduce or eliminate water pollution from feedlots with minimum expenditures.

More costly control measures, at least in terms of capital investments and operating costs, would include systems with completely covered feeding operations and full treatment of the wastes. Of course, between the minimal control situation and the maximum control situation there are numerous other control measures and combinations of these measures that can be used.

The type of control measure adopted depends upon a variety of factors chief among which are the quantities of water that must be contained or diverted, the possibility of cost savings, and the ability of the system to offset inadequate labor supplies. Intertwined with these chief factors in determining the type of control measure to be adopted are such things as lot size, climate, and type of feeding operation. These factors are, of course, reflected to an extent in the present geographical distribution of feedlots by sizes throughout the United States.

Major Feeding States

The 32 major feeding States accounted for over 23 million head of cattle marketed from feedlots in 1968. About 20.2 million head were marketed from feedlots in the 14 States with the largest marketing from feedlots in 1968. It is therefore apparent that the bulk of the feedlot cattle operations are concentrated in relatively few States. Even more important from a water pollution standpoint is the fact that cattle feedlots are generally more heavily concentrated in specific sections of these States. As a result, the pollution potential, both in total magnitude and in the cumulative effect along a watercourse, is very high for such localized areas.

Feedlot Capacities

Feedlots with capacities of 1,000 head or over accounted for almost half of the total cattle marketed out of feedlots in 1968. However, by virtue of the capacities of these larger feedlots, they only account for about one percent of all feedlots. In other words, the 2,080 lots of 1,000 head or over capacity marketed almost 11 million head of the slightly more than 23 million head marketed from all feedlots in 1968. The other 206,516 feedlots of less than 1,000 head capacity accounted for the remainder of the cattle marketed from feedlots.

Almost 90 percent of the cattle from feedlots with capacities of 1,000 head or more come from 10 States west and south of the Missouri River. These States account for 1,522 of the 2,080 feedlots reported to have had a capacity of 1,000 head or more in 1968. On the other hand, 10 midwestern States, including an overlap of Kansas and Nebraska previously included in the large lot category, account for the bulk of the small feedlots and cattle marketed from them. These 10 States account for 185,264 lots out of the total in this under 1,000 head size group of 206,516 and for about 10.6 million out of a total of 12.2 million head marketed from this smaller size group.

Many of the lots of under 1,000 head capacity are extremely small. The average size of lots under 1,000 head in the five States with the largest number of feedlots is only 65 head and the average of the 10 midwestern States is 57 head.

As would be expected, the number of feedlots in each size category declines very rapidly as the lot capacities increase beyond 1,000 head. However, the trends indicate that all feedlot sizes will be increasing and that there will be continued growth in the numbers of large-scale lots. The 32-State totals show that the bulk of the 1,000 head capacity lots fall within the 1,000 to 3,999 head capacity range. In fact, if the range is expanded to include up to 7,999 head capacity lots, this new range includes 1,805 of the 2,080 lots with capacities of 1,000 head and greater.

From the foregoing discussion it is evident that there are some definite points to be considered when assessing the need for, and applicability of, different pollution control measures for various sized feedlots. Additional breakdowns of the large-scale feedlot figures show that 90 out of a total of 99 feedlots with capacities of 16,000 head and over are accounted for by nine of 10 top States in cattle marketings from lots over 1,000 head capacity. Also, it shows that these 10 States account for 252 of the 275 lots with capacities of 8,000 head or more.

Feedlot capacities cover the broad spectrum of size ranges from less than 50 head to over 30,000 head capacities. However, there are definite groupings of lot sizes within this range. These size groupings, although not all-inclusive, follow a general geographic pattern related to climate. Most of the large feedlots, for example, are located south and west of the Missouri River. Although specific feedlot locations and corresponding climatological data are not presently available, it is known that the climate is less severe in most of these States than in the States where the majority of the small lots are located. In fact, in several of the States with the majority of the large lots, the climate can be considered as dry.

Another perplexing problem, in terms of evaluating the current pollution problem and forecasting future changes, is how to differentiate size groups in the 206,516 lots of under 1,000 head capacity. In this size group the average number of cattle marketed in 1968 was 59 head. Even if the lots are restricted to those found in the 10 midwestern States with somewhat similar climatic conditions, the magnitude of the problem remains large. That is, in these 10 midwestern States there were 185,264 lots of under 1,000 head capacity. About 10.6 million head of cattle were marketed out of these lots in 1968 for an average marketing of 57 head.

INTRODUCTION

Previous Cost of Clean Water reports have covered the basic questions with respect to animal wastes. In brief, they point out that water pollution from animal wastes is a very significant and growing problem. These conclusions stem primarily from information on total wastes produced by farm animals, the growing demand for animal products, and trends toward fewer farm units with greater concentrations of animals on the remaining units.

These earlier reports, as well as many other past and current reports, rely heavily upon showing the gross magnitudes of animal wastes produced. These gross figures are often cited in hopes that they will lead readers to the inescapable conclusion that, even after discounting for overstatement, animal wastes are still a serious problem.

Despite the value of using this gross magnitude method to make people aware of a problem, there is an obvious drawback in that people may either overreact and conclude that the problem is too big to handle or underreact and conclude that such figures are too far off target to be taken seriously. Therefore, in order to receive the needed understanding and support for pollution control efforts in the animal wastes area as well as to develop plans for attacking the problem, it is necessary to have available some reasonable estimates of the true magnitude of the problem.

Although these other reports drew some very broad conclusions as to the magnitude and future of the problems, they did point out that little was known about the actual amounts of pollutants reaching the waters, the available control measures, or the costs of these controls. This current report also admits to a lack of data regarding the aforementioned items, however, this section's objective is to provide a comprehensive view of the problem, to setup a framework that can be used for future study, and to discuss the known facts and point out areas with potential for fruitful future study. This report concludes that water pollution as a result of improper or inadequate disposal of animal wastes can be a major but manageable problem. It also points out that further study may show that in many cases the net costs of control may not only be manageable but very minimal, if at all existent, when offsetting economies of the changed operations are considered.

Water Pollution Control and Wastes Management

The characteristics and volume of animal wastes produced daily preclude a simple separation of the water pollution aspects from the total problem of waste management. Actually, operators of animal raising or fattening enterprises are often more concerned with the total wastes accumulated in their operations than they are with the amount of water pollution caused by these wastes.

An operator's concern with the wastes accumulations is understandable in that the problems and costs associated with waste management in large scale operations are immense. It is, therefore, desirable and advisable to view the water pollution control aspects of the enterprise's wastes as a part of the overall waste management system. Also, it is likely that in many cases changes in waste management practices will result in water pollution control. Conversely, adoption of a water pollution control system might result in a solution to the waste management problem.

OVERVIEW OF ANIMAL WASTES PRODUCTION

From an overall point of view, the water pollution potential of animal wastes hinges upon the demand for all animal products. Increasing consumption means that more animals must be raised to meet the rising demand, whereas, decreasing demand causes an opposite effect on production. The result of raising more animals to meet a rising demand is a corresponding increase in animal wastes produced.

The actual change in quantities of wastes produced depends upon the types of animal products demanded. For example, beef cattle wastes are much different quantitatively and qualitatively than poultry or swine wastes. This means that as the demand for one type of meat changes, the pollution potential of the entire industry changes in proportion to the wastes of that species. However, the potential does not change in a simple one-to-one ratio that would occur if all the waste characteristics of each animal species were the same.

An example of a one-to-one change would be where the demand for beef increased by a certain number of pounds while the demand for poultry decreased by a like number of pounds leaving the total demand for meat unchanged. In this case a one-to-one ratio for waste characteristics would mean that there would be no net change in: total wastes produced; their characteristics; or their potential for entering a watercourse.

Because there is not a one-to-one wastes ratio, any definitive estimate of the cost of controlling wastes from meat animals requires, in addition to analysis of technical questions on waste production and control, projection of consumption and production trends for each animal species. Similar production and consumption factors will also have to be analyzed to predict the costs of controlling wastes from dairy animals.

The major objectives of this section are to define the animal wastes problem and to set forth a framework for estimating costs of controlling these wastes to whatever degree necessary to prevent water pollution. Since the report is of a preliminary nature, it is premature and unnecessary to delve deeply into the consumption and production trends of the various animal species. Rather, a superficial look at these trends to gain some insight into the potential of the problem is adequate until we can come to grips with the technical aspects of such things as runoff prediction, acceptable treatment or control measures, and estimating costs of providing the various treatment or control measures.

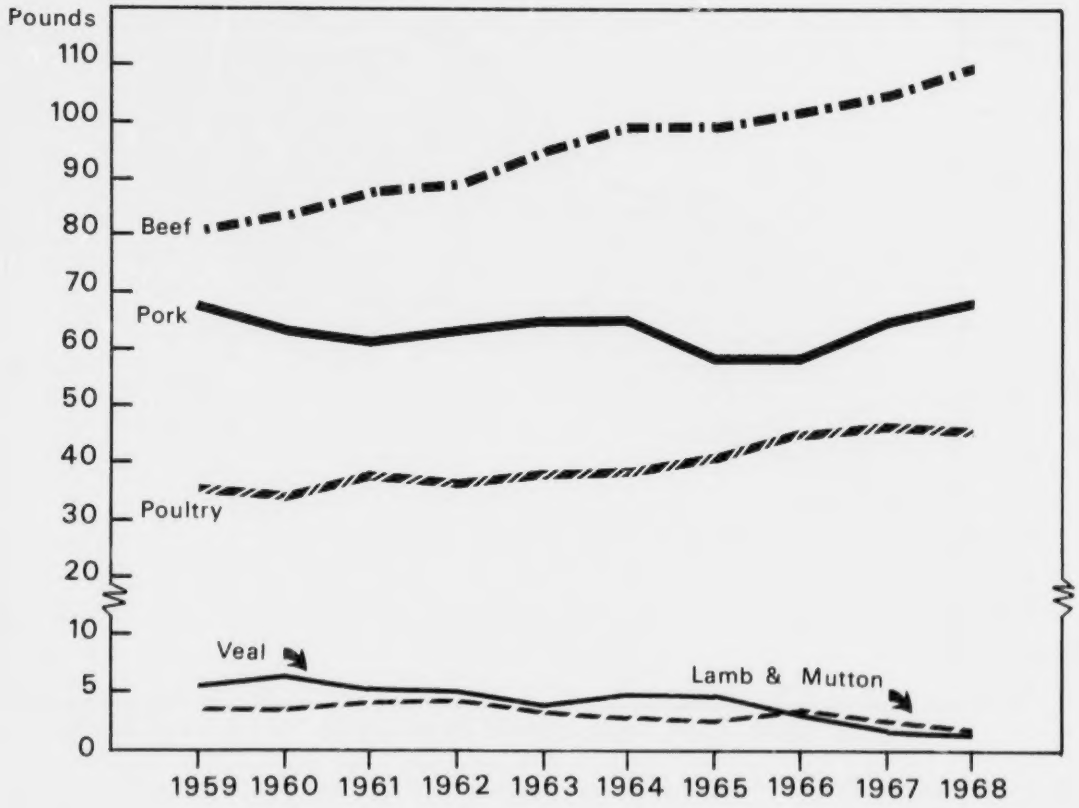
Trends Affecting Animal Numbers

Meat consumption in the United States has been trending upward over the years. This upward trend has been evidenced in both the per capita consumption and the total consumption figures. Although many factors affect meat consumption, it is generally agreed that per capita consumption is directly related to disposable income. Income also has an effect upon the preferences of people when choosing among meat products. Per capita beef consumption, for example, usually increases as incomes rise even though consumption of pork, poultry, or lamb may be falling during the same period. (See Figure 1.) A comparison of Figures 1, 2 and 3, shows the result of the interaction between consumption, population, income and other related factors that affect production.

As can be seen in Figure 2, the pounds of meat produced annually, which is an indicator of consumption, are increasing at a rather steady rate that is probably directly related to population and income. If population and income projections for the next several years prove accurate, then the increases in animals raised or maintained to meet the greater demand for meat products will significantly compound the animal wastes disposal problem. Certainly the effect of population will not be reversed although there may be a change in the slope of the population trend. Figure 4 shows the population trend in recent years and the census projection through 1975. In general, then, it is reasonable to conclude that a more detailed study of animal wastes production from a potential water pollution source standpoint is warranted. As necessary, a more detailed review of the consumption and production trends within any phase of the animal industry will be given in the appropriate section of this report.

Figure 1

Per Capita Consumption--Beef, Pork, Veal, Lamb and Mutton, and Poultry, 1959 through 1968.

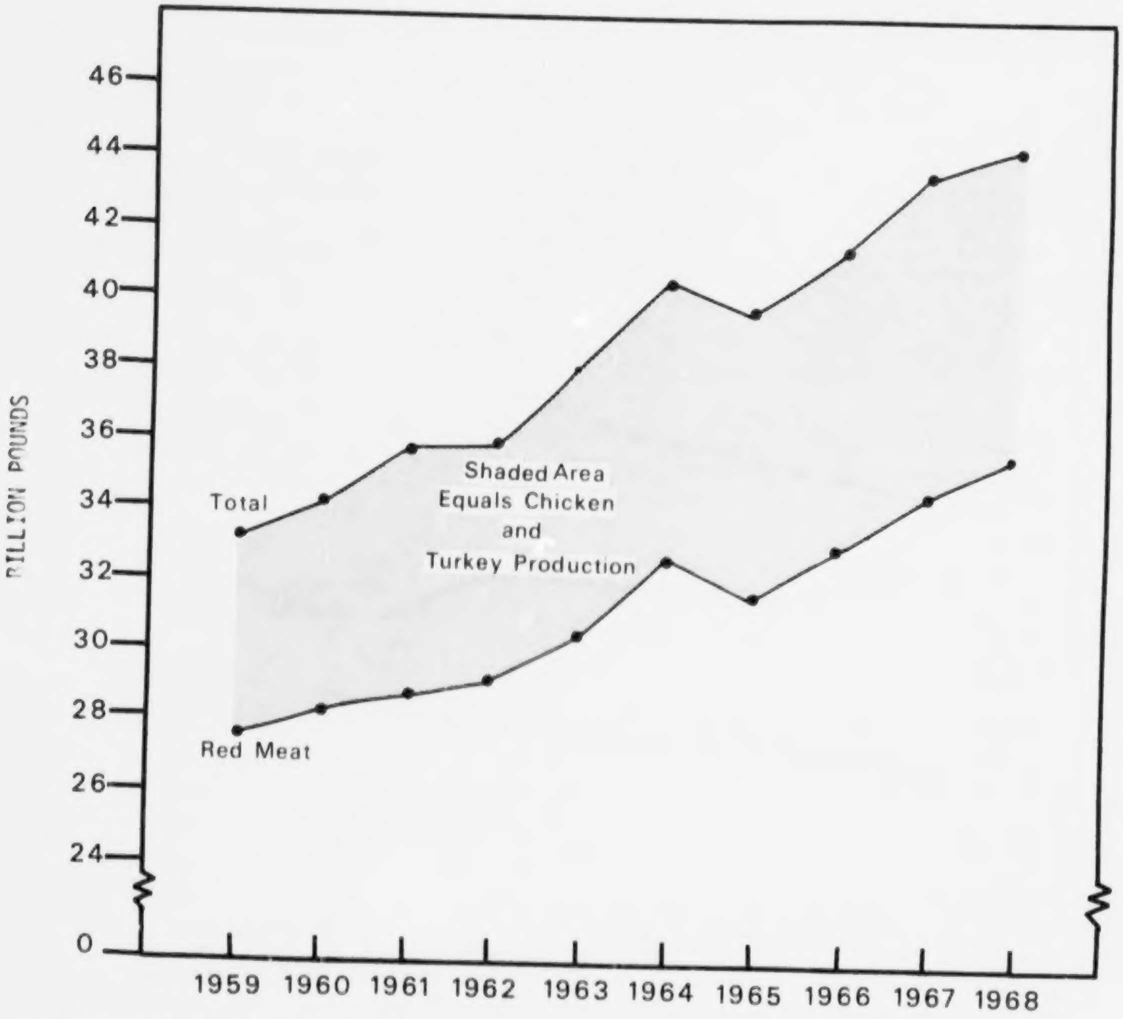


SOURCES: Livestock and Meat Statistics-Supplements for 1967 and 1968 to Statistical Bulletin No. 333, U.S. Department of Agriculture Economic Research Service-Statistical Reporting Service-and Consumer and Marketing Service, Washington, D.C.

Poultry and Egg Situation-June 1969, Economic Research Service, United States Department of Agriculture, Washington, D.C.

Figure 2

Production of Red Meat and Poultry, 1959 through 1968.

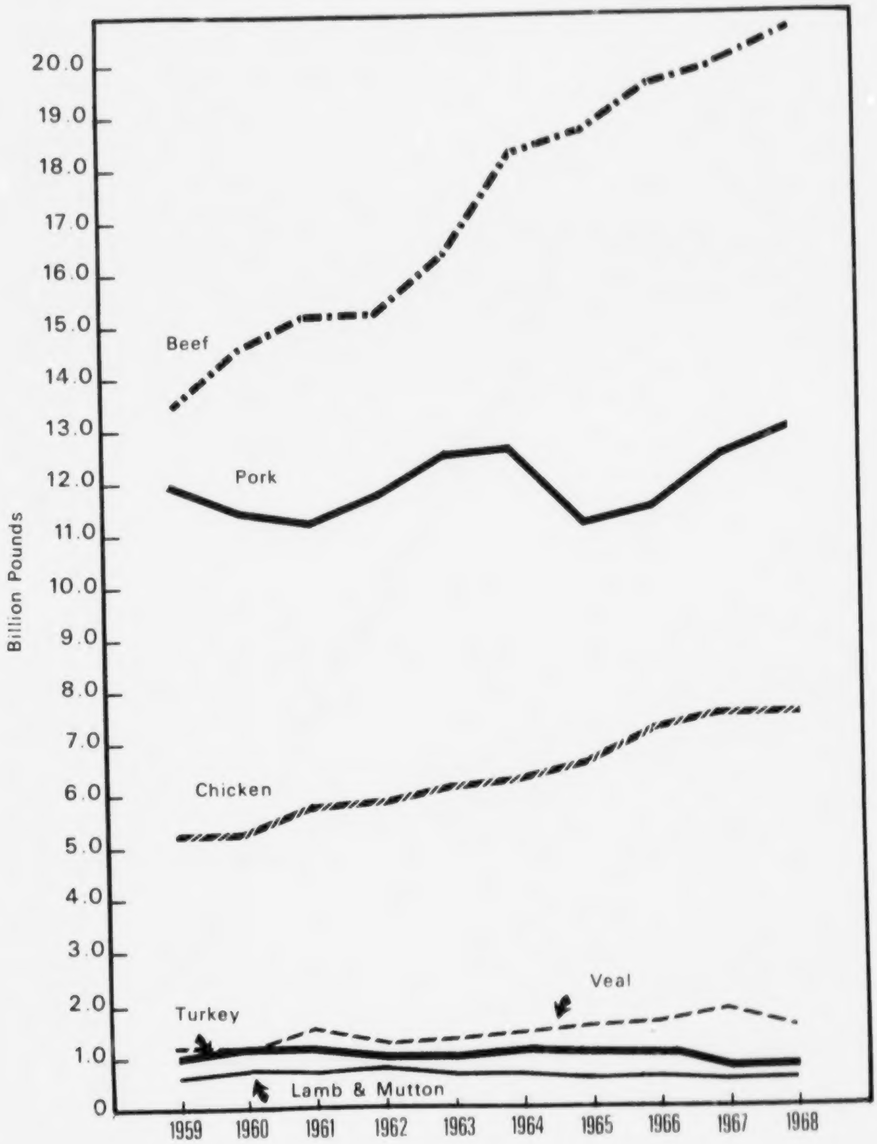


SOURCES: Livestock and Meat Statistics—Supplements for 1967 and 1968 to Statistical Bulletin No. 333, U.S. Department of Agriculture, Economic Research Service, Statistical Reporting Service, and Consumer and Marketing Service, Washington, D.C.

Poultry and Egg Situation, June 1969, Economic Research Service, U.S. Department of Agriculture, Washington, D.C.

Figure 3

Meat and Poultry Production, 1959 through 1968.

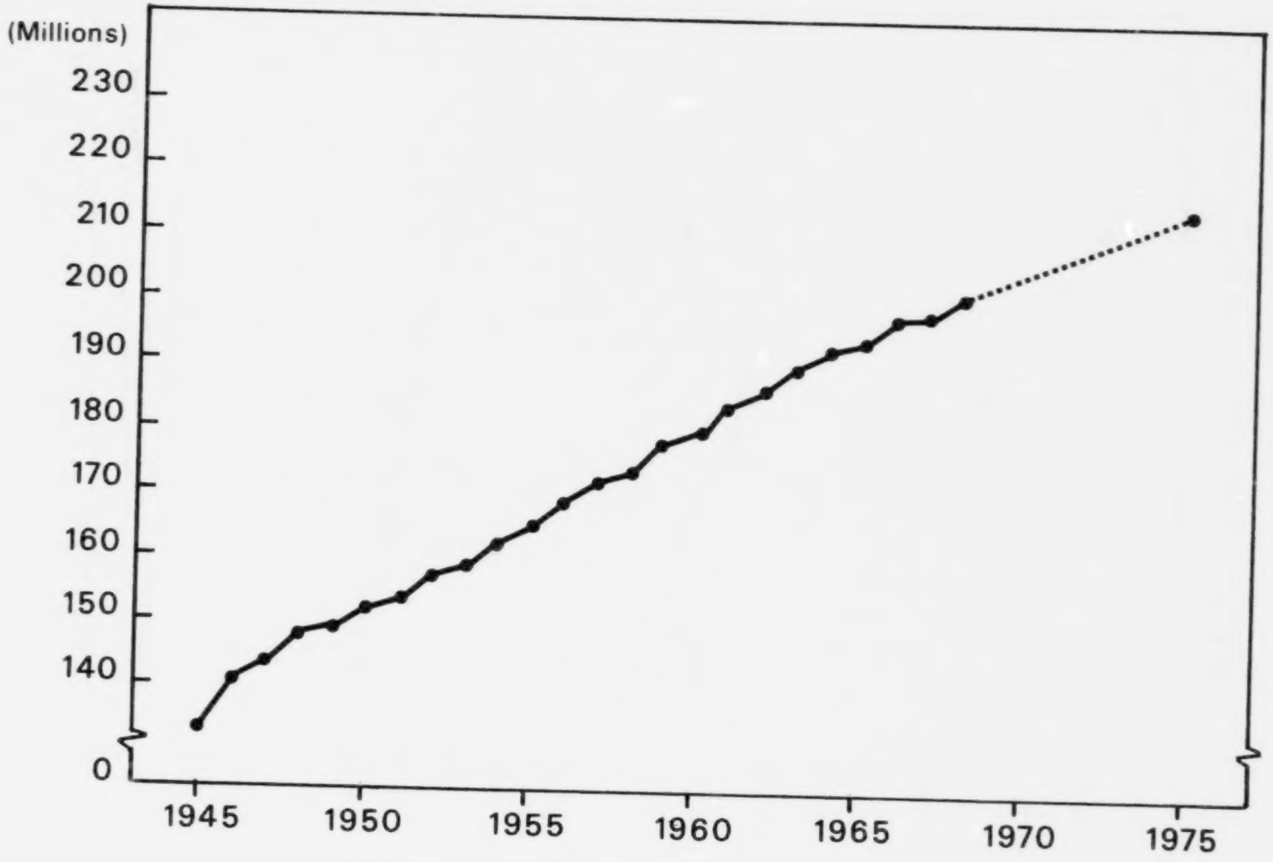


SOURCES:

Livestock and Meat Statistics--Supplements for 1967 and 1968 to Statistical Bulletin No. 333/U.S. Department of Agriculture, Economic Research Service-Statistical Reporting Service- and Consumer and Marketing Service, Washington, D.C.

Poultry and Egg Situation, June 1969, Economic Research Service.U.S. Department of Agriculture Washington, D.C.

Figure 4
United States Population, 1945 through 1968 with Projections for 1975.



SOURCE: Current Population Reports, Bureau of the Census, United States Department of Commerce.

OVERVIEW OF COST ESTIMATION

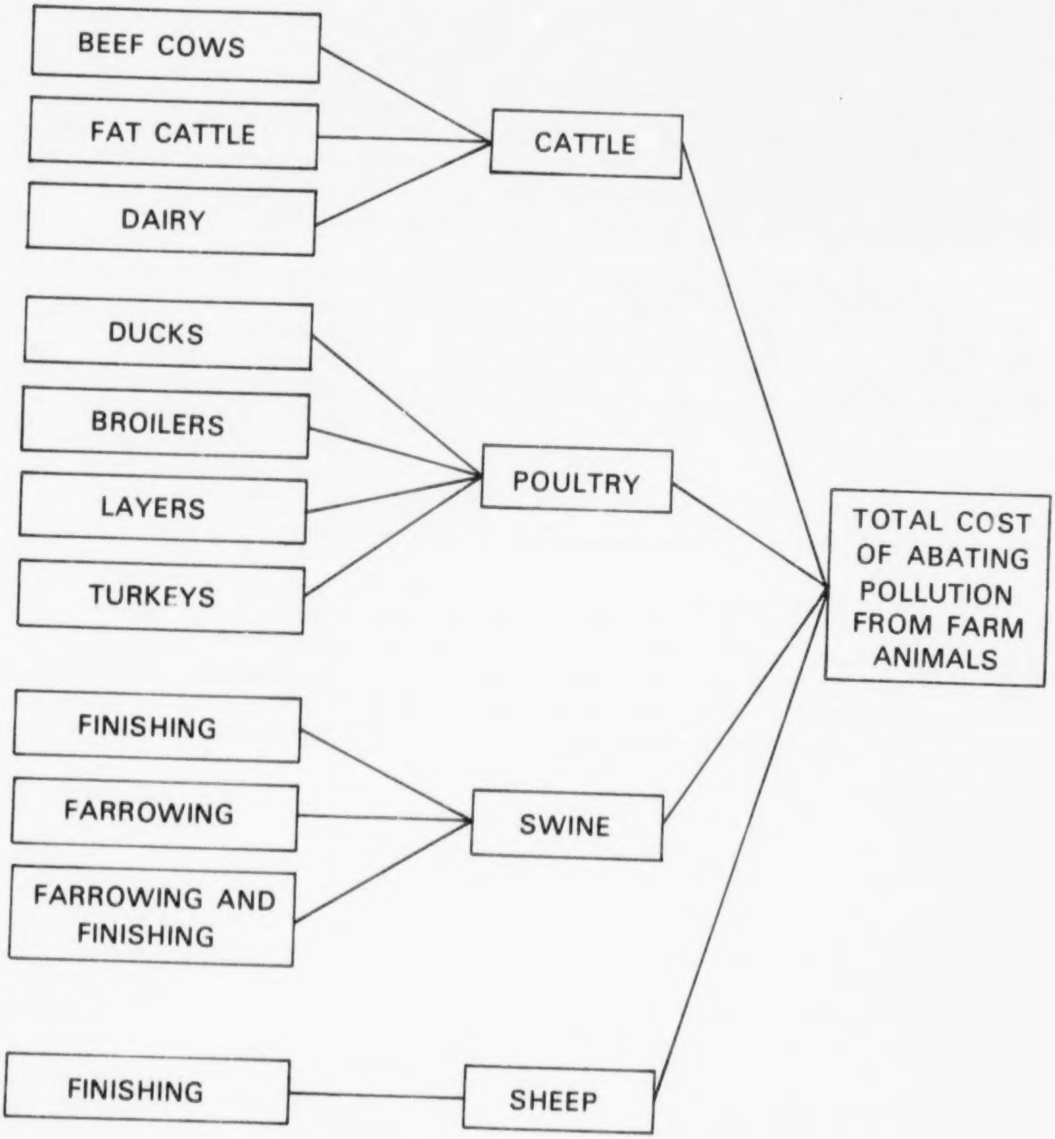
Estimation of the costs of controlling water pollution from animal wastes is indeed a complex issue that involves three major categories of study and all of their individual ramifications. The three major points are; (1) determing the volume and characteristics of the wastes that actually reach the water: (2) applying the applicable control measures to the offending wastes; and (3) estimating the cost of these control methods for the entire industry. Although there is no specific discussion of groundwater pollution from animal wastes in this report, it is recognized that soil pollution may prove significant in the future. However, for report purposes it is assumed that groundwater protection can be achieved through proper design of lagoons, detention ponds and confinement areas.

In studying the situation for this report it became clear that one valid approach to fully assessing the problem would be to describe and categorize waste dischargers and then break the animal wastes issue into several logical sub-elements to be dealt with in the required detail as time, knowledge, and monetary restrictions permit. Using these procedures, studies of each sub-element can be completed individually and later combined with studies of the other sub-elements to arrive at an estimate of the total cost of abating pollution from these animal sources. The diagram in Figure 5 shows the major details of these sub-elements as they are used in the report.

As each component is discussed, i.e., cattle, swine, poultry, and sheep, the known factors about each one are summarized. This summary statement covers such things as the pollution potential, the unanswered questions, and the status of ongoing studies. Because of the emphasis placed on the cattle industry this year, that section will be the most comprehensive and will provide the greatest amount of detail.

Figure 5

Major Components of the Farm Livestock Industry That Must Be Analyzed to Estimate Water Pollution Control Costs.


BEEF COWS
FAT CATTLE
DAIRY
CATTLE
DUCKS
BROILERS
LAYERS
TURKEYS
POULTRY
FINISHING
FARROWING
FARROWING AND FINISHING
SWINE
FINISHING
SHEEP
TOTAL COST OF ABATING POLLUTION FROM FARM ANIMALS

COMMON CHARACTERISTICS OF ANIMAL WASTE DISCHARGES

To the extent feasible the animal wastes problem will be discussed in the smallest component part. However, there are some characteristics that are common to most, if not all, the components and these will be discussed initially to simplify the discussion and aid in its understanding. These common characteristics are related to the frequency of pollution and are defined under the headings of"regular", "intermittent", "seldom", and "never". This categorization is important when estimating the pollution potential as well as the types of control measures that will be required.

A complicating factor in the assessment of animal wastes that cause water pollution is the variability of waste discharges. In municipal and industrial situations wastes are usually discharged on a regular basis. This is not to say that there is no variability in industrial or municipal waste discharges, but only that there is basically a day-in and day-out discharge pattern from these sources with the variability falling mainly in cycles within these regular patterns. For example, a residential section will dispose of its wastes daily. However, within any given day there will be high and low discharges for the group as there will be high and low discharges on a seasonal basis. Despite such internal variability there is the daily regularity which allows reasonable estimates to be made of the volume of waste discharge and makes feasible a continuing operation for the treatment and disposal of this type of waste.

Animal wastes, on the other hand, are not discharged with the same regularity on a gross basis. If one considers any waste carried in a fluid medium from the animal confinement area to a watercourse as a discharge, then dischargers can be generally classed as regular, intermittent, seldom, or never.

Regular dischargers may be defined as those discharging on a daily basis. Intermittent dischargers are more difficult to define since they cover the broad range from several discharges per year up to something less than daily discharges. Dischargers labeled as seldom are those that have a discharge frequency of around two or three times per year. Although labeled as never dischargers, those falling in this category can have an occasional wastes discharge but only in a very unusual circumstance. For example, floods in areas not normally subject to flooding, extremely severe rainstorms, or other similar rare occurrences that result in water pollution from the animal operation are discounted and the discharger is considered as falling in the never category.

Regular Dischargers

Those operations discharging on a regular basis may use a variety of methods to collect and transport their wastes. However, the most common ones of concern are the swine, dairy, and poultry operations using water flushing systems, the special cases of duck raising enterprises, and the animal units in direct stream contact. Although there are several methods or combinations of methods that might be used in any given water flush operation, only a single method for each different type of animal enterprise will be described here.

Before describing a particular type of water flush operation it will be helpful to point out some of the common reasons for, and characteristics of, hydraulic or water flushing. Hydraulic flushing is, by and large, used to reduce labor time in cleaning operations or to increase the effectiveness of the cleaning operation. These two factors are, of course, interrelated but either one alone can be the deciding factor when an operator is considering the feasibility of installing a hydraulic flush system.

Benefits from water flushing are manifold, but chief among them are reduction of nuisance problems, reduction in labor costs, or increased labor efficiency. Nuisance problems are decreased because of the higher quality cleaning possible and the increased frequency of cleaning possible with the use of a water flush system. The higher quality and increased frequency of cleaning helps to reduce odor, disease, and fly problems.

Water flushing usually increases the capital investment required for the enterprise but decreases the amount of labor required for the cleaning operation. Lower labor costs and decreased death losses or increased gains attributable to better cleaning can offset some of the increased capital costs, but, in most cases, the primary attraction is the enterprise's ability to maintain the same size operating unit with less labor or to increase the animal capacity without increasing total labor needed for the entire enterprise.

A common problem associated with water flushing is the inability of the water to remove the collected debris and manure under certain unfavorable conditions. These unfavorable conditions may vary from freezing in the cold climates to drying and packing in the hot climates. Design and operation problems encountered include floor slopes not geared to the flush volumes, slopes not designed to minimize water use, and the use of bedding material that is not readily flushed by the water system.

As far as debris is concerned, its flushability is primarily dependent upon its size and compaction. Large chunks of any substance that will not break up or readily dissolve cannot be flushed satisfactorily. Stalks of corn, hay, or straw have a tendency to tangle together and drag during the water flush. Therefore, bedding of a straw nature is not used with a flush system. By the same token, hay is not fed in the stall area where it can be dropped in large quantities and interfere with the flushing operation.

Unless it is solidly packed or frozen, manure can be flushed with relative ease. Therefore, to assure that the flushing action is effective, it must take place frequently enough to prevent drying and packing or a buildup too great to be washed away. This usually means flushings of at least twice a day and often more frequently. Freezing presents a much different problem in that flushing systems probably cannot be used in very cold climates unless the entire system is enclosed and, in some cases, at least partially heated. In moderate climates frequent flushings may prevent hardening of the manure and resultant poor results from flushing.

In general, it can be assumed that operators will try to minimize the amount of water used in the flush systems. When water use is minimized it means that the concentrations of pollutants increase per remaining unit of flush water. Even if a maximum of water were used for dilution purposes, the concentrations would still be too high to allow the wash water to flow directly into a watercourse. This is true because of the sheer volume of wastes produced daily by animal enterprises large enough to economically use a flush system. The suggestion that these flushing wastes be placed on the land through spray irrigation is probably valid but care must be taken to assure that the wastes cannot be eroded into the watercourse at a later time.

Water flush systems are usually not readily adaptable to most of the existing farm animal enterprises. In most cases the floor slopes need to be modified, stall widths and lengths changed, and in some cases, the location of the pens or buildings will have to be changed when a flush system is installed in an existing facility. In all cases tanks must be installed, gutters modified, and a drainage, holding and removal system integrated into the flush arrangement.

Although there are many problems involved in adapting an existing facility to a flush system, there are many animal units that can be so adapted with a minimum of extra problems. In addition, all new facilities can be designed to accommodate a flush system. Therefore, it is important that some helpful criteria be developed to assure that new flush systems do not contribute to the water pollution problem and so that existing systems can be modified to abate any water pollution.

Description of Water Flushing Methods used in Dairy, Swine, and Poultry Operations

Dairy. Cow milking operations on a large scale may employ a water flush system that includes both a milking parlor flush and a loafing area flush. As the cows enter the milking parlor they are washed down in the area of the udder, either by a spray nozzle or by hand washing. The quantity of manure that is washed off the udders of all the cows during the operation is relatively small but the concentration per unit of water is still fairly high. After the cows have been milked the entire parlor is washed down to remove all manure which had been dropped while the milking process proceeded. In addition to cleaning up the parlor and milk house proper, the milking utensils, pipes and other equipment must be washed. In this regard, many dairy farms utilize a milking parlor and are faced with this volume of water disposal even though they do not use water flushing as described in the following section relating to the areas where the cows are kept between milkings.

In a free-stall setup the animals are kept in a confined area with sloping concrete floors. The entire arrangement is designed to assure that the animal feces will be dropped on the floor where they can be readily washed down. Tanks with drop gates are placed at the upper end of the sloping pens. A hydraulic head is built up when the tanks are filled with water. At the prescribed cleaning time the gates on the tanks are dropped and the water rushes out and down the sloping floors carrying the manure and debris with it. Some observed flushing operations such as just described use as much as 50 to 60 gallons of water per day per cow to clean these confinement areas. Even considering a system designed to minimize the amount of water required, the water use per day would amount to around 20 gallons per cow with no decrease in the amount of solids removed.

After completing its flush, the water may be sent into a stream, a lagoon, a natural or manmade ground channel, or used for irrigation purposes. It is at this point that water pollution control officials become concerned with the material collected during the flushing operation, since it may be discharged directly or indirectly into watercourses or it may be allowed to sit for some period near the watercourse and later washed in by water from melting ice and snow, or from rains. In any case, the pollution load for any receiving watercourse can be very severe since many of the dairy enterprises utilizing a flush system will be units with 100 cows or more.

A description of a water flush system used in swine enterprises will be quite similar to the free-stall housing flush system. However, the volumes of water used and the method of flushing will vary.

Swine. Hogs are apparently cleaner by nature than the other animals raised for food. For this reason, a flush system is more readily adaptable to a swine operation. In many swine barns the floors are sloped from the center to the outside edges and the entire floor is sloped lengthwise. In this manner any liquid in the unit would tend to move to the outside edge and down to the end of the unit. Gutters built into the floor along the outside edges of the building make an excellent channel for the flow of water during the flushing operation.

In most cases, the hogs will learn to defecate in the channel so as not to dirty their pens. Therefore, it will usually not be necessary to flush down the interior of the pen although it is easy to use a hose and wash down this area if the hogs become sloppy. Use of a gutter in this fashion tends to minimize the amount of water required and, at the same time, maximize the concentrations of pollutants in the flush water.

At this point, the problem becomes almost identical with the one described for the dairy operation, that is, how to collect and dispose of the flush water in the most efficient manner without causing pollution problems. The same disposal methods and constraints as previously described for dairy enterprises also apply to the swine enterprises.

Poultry. For our purposes, poultry enterprises are considered in three broad groupings: (1) broilers and layers; (2) ducks; and (3) turkeys. There is no single management technique currently applied to all types of poultry enterprises, just as there is no single technique applied to any of the other animal raising enterprises that are discussed herein. However, a brief discussion of the types of water pollution problems associated with each type of poultry enterprise and a description of some of the waste handling systems in use can be useful in categorizing the water pollution problems caused by the enterprises.

Water pollution as a result of broiler and layer enterprises can range from the regular to the never categories of discharges previously discussed. Turkey enterprises will often fit the intermittent discharger category while duck raising enterprises generally fall into a special type of regular discharger category.

Broiler and layer. Poultry enterprises have probably had more experience with a water carriage waste handling system up to this time than any of the other animal enterprises. Here again, the system was primarily developed to aid in removing the wastes with a minimum amount of labor and to provide a maximum practicable amount of cleanliness. In other words, the system design did not, in most cases, consider the broad effects of the wastes upon the environment after their removal from the animal areas.

An example of a system discharging on a daily basis would be a combination of mechanical scraping and water carriage of the wastes out of the pen area. In this system the water flows through a sloping gutter during the cleaning operation so that wastes can be scraped from the floor or dropping shelves into gutters. Another variation uses water instead of a scraper to move the wastes into the gutter. This latter method employs the use of a hose and pressure nozzle to flush the wastes from the floor or dropping boards into the gutter. In any case, the principle is to remove the wastes from the cages or pens in the most advantageous manner and dispose of the wastes through some subsequent operation. Such subsequent disposal operations might include irrigation of the effluent, hauling and spreading as a slurry, or in extreme cases, direct disposal of the wastes into a watercourse.

Water flush systems similar to those described for hog and dairy enterprises can also be used in poultry systems although some difficulty may be encountered in assuring that the wastes are adequately scoured from the floor surfaces. The special problems involved are the moisture content of the wastes to be removed and the absence of scouring particles in the waste materials.

Water flush or carriage systems will work equally well for all of the broiler and layer enterprises, however, climatic factors are major influences on the type of waste handling system presently in use. In arid areas a system that takes advantage of natural drying conditions may be preferable while the most advantageous system in humid areas may be one that uses water as a transport and/or flushing medium.

Although there may be many disposal systems employed by variations of the regular dischargers, the only other ones discussed here are specialized duck raising operations and those operations that allow their animals free access to a watercourse.

Duck raising enterprises present a problem similar to that of a flushing operation but the intent as well as the effect is different. In a typical duck raising setup the ducks are grouped along a flowing channel of water by ages. The result is like a staged continuum with the birds phased along the water channel from birth to slaughter.

The flowing water, among other things, aids in the development of a marketable feather from the bird. At the same time, it carries the wastes that are dropped in the channel into a receiving watercourse. In addition to the regular nature of these wastes being carried by the channel, there is a problem of slug loads occurring during rainstorms. Since a large part of the duck's time is spent out of the water, there tend to be sizeable accumulations of droppings along the sides of the channel between cleaning operations. During rainstorms the accumulated droppings are flushed into the channel and carried into the watercourse. The resulting slug can be devastating but the effect is dependent upon factors such as the number of ducks, amount of waste accumulation, length of storm, and volume of water.

From a national viewpoint duck raising enterprises do not constitute a major problem because of the limited number of enterprises needed to fill the demand for ducks. However, from a local point of view, the duck raising operations can be a serious problem. Also, for this report they provide good examples of work that has been done to abate pollution from animal raising enterprises.

Direct Contact of Animals with WaterCourses

Occasionally, animal raising enterprises are set up so as to take advantage of the watercourse for stock watering and/or cooling. In such cases the scope of the operation, in terms of number of animals, usually would fall in the small category.

Fences are used to set off a particular stretch of stream along with needed grazing or confinement areas for the animals. In this manner the animals are free to wander within the fenced area and make full use of the stream for watering or such comfort purposes as cooling or keeping insects away. For whatever reasons the animals use the stream they tend to pollute the water during that use.

The simple process of the animals drinking from the stream, for example, can cause pollution from sediments knocked into or stirred up in the streambed. Of course, it must be recognized that in most small operations there is no measurable pollution produced in this manner. However, where the concentration of animals is heavy, there can be significant sediment problems caused by the continual dragging of debris into the stream and the constant mixing and churning of the bottom muds by the animals' feet. In addition, if the stream is situated so that the animals use it for comfort purposes or spend significant amounts of time next to it, wastes dropped by the animals themselves can create sizeable pollution loads. That is, the wastes can be dropped directly into the stream while the animals are using it for comfort purposes. This can cause a pollution load if the numbers of animals are large in relation to the stream size. On the other hand, if a significant buildup of wastes occurs on the banks even a small number of animals could place a harmful slug load of pollution in the stream during a flushing rain.

Intermittent Dischargers

For the most part, intermittent dischargers do not deliberately pollute the water or even knowingly permit conditions that allow the waters to become polluted. An example of an intermittent polluter might be a feedlot operator whose lot is hard surfaced and well away from any stream or drainage course that reaches a stream but who spreads the manure during cleaning operations on fields that are near to streams or direct drainage courses. Once the manure has been spread it can then be washed into the streams by ensuing rains or by waters flowing from spring thaws. Similar situations could arise for any animal raising enterprise. The critical factor in these cases is not the production of the manure or the vagaries of the elements but rather the deposition of the wastes where they are subject to washing into a watercourse.

Other intermittent dischargers include operators of open confinement lots that are located so that a heavy rain or series of rains can wash wastes from the confinement area into a watercourse. In these cases the critical factor is the location of the confinement area and the fact that the elements can cause a discharge without any physical movement of the wastes by the operator of the animal enterprise.

There are, of course, cases of intermittent polluters that deliberately release or dump animal wastes from their enterprise into watercourses. In some cases this may amount to loading and hauling the wastes to the stream. In other cases it may be that the wastes were contained in a pit or other detention system until cleaning was needed and at that point flushed into a drainage channel or watercourse.

Another possible intermittent polluter might be the conscientious operator who is trying to prevent pollution from his enterprise but has an under-designed prevention system. This could occur when a lagoon or detention pond has been built to contain or treat the wastes but the pond is not large enough to hold the water accumulation from extended or severe rains.

The following examples of animal enterprises that might be considered as intermittent polluters will help to clarify how these operations contribute to water pollution and what possible means might be used to curb such pollution.

Probably the most common cause, on a purely numerical base, of water pollution from animal feeding enterprises is carelessness. That is, on a day-in and day-out basis most intermittent pollution is caused by operators who do not realize that they are causing pollution or who think that their contribution to water pollution is too insignificant to cause a problem. Such an operator might be one of the thousands of small feedlot operators scattered throughout the midwestern United States. These operators generally feed from 25 to 100 head of cattle on a seasonal basis to provide an outlet for their surplus labor during the winter months.

The animal feedlot confining only a few head through the winter will not have much runoff in the winter months. However, when the spring thaws begin there will be substantial quantities of liquids laden with animal wastes running from the confinement area.

Since runoff will follow a natural drainage path, there is a strong possibility that during rainstorms or rapid thawing conditions the wastes will reach a watercourse. It is easy to see that the prime factors influencing the amount of such runoff reaching any given stream are the: (1) size of the feedlot; (2) size of area draining across the lot; (3) number of animals; (4) surface and slope of the lot; (5) proximity of the lot to the stream; (6) amount of rainfall or water stored as ice and snow in the lot or drainage area above the lot; (7) terrain between the lot and the stream; (8) duration and amount of rainfall; (9) condition of the lot prior to the rain or thaw, including antecedent rainfall and frequency of cleaning; and (10) temperature conditions.

Feedlots containing more than the 100 or so animals used in the preceding section as an arbitrary upper limit in defining small feedlots, may also contribute to water pollution. In fact, the same factors that influence the amount of water pollution from small lots influence the amount of pollution from larger lots. However, the larger the lot, the more likely that the operator recognizes that the wastes from his lot can cause water pollution. Thus, it is more likely that he has taken at least some steps to mitigate or prevent such pollution. For this reason the larger lots are probably intermittent polluters because of accidental releases or overflows rather than from lack of understanding and some efforts to avert the problem.

Efforts by feedlot operators to preclude runoff pollution from their lots have, in the past, usually been minimal and often consisted of diversion ditches, detention ponds, lagoons, more attention to cleaning the lots and solid waste handling, or some combination of these methods. Since there is no profit for the operator in providing water pollution control, the efforts to prevent pollution are minimal and, therefore, the control measures are often poorly designed.

A more detailed discussion of control methods and cost factors for water pollution control from feedlots can be found in the "Feedlot Pollution" section of this report. However, the following review of the diversion, detention, irrigation method is presented here as an example of how a large scale feedlot operation can become an intermittent polluter. Specific types of control measures that might be used by a large feedlot operator might include a series of diversion ditches in combination with a detention pond for holding any runoff. The diversion ditches are designed to keep water from flowing onto the lot from other areas upgrade from the lot. The diversion ditches will usually be built around the upper end of the lot and along its sides, with the collected water channelled into a drainage area away from the feedlot. The detention pond, on the other hand, is designed to hold the water that runs off the lot itself, or from the lot and necessary driveways, or work areas.

A detention pond in most cases is not built to hold a large accumulation of water over an extended period of time. Rather, it is designed to hold expected rainfall over some given period and is then to be emptied in preparation for the next rainfall. The most common method of emptying a detention pond is through use of a pump from the pond through the irrigation system onto land or crops for ultimate disposal.

Poor design of the pollution prevention system just described can cause or lead to water pollution through excess runoff overflowing the pond, or through improper use of the irrigation equipment. In most cases this poor design is a result of the feedlot operator's efforts to minimize expenditures for pollution control measures. Cost minimization, in the absence of enforced penalties for pollution, involves a calculated risk with respect to possible pollution situations. That is, the system is designed to accommodate about the median rainfall situation over the years rather than the maximum situations. As a result, during periods of high or extended rainfall the system becomes overloaded and water pollution may occur.

Cost data are not available and would certainly vary from location to location but some generalizations can be made about factors affecting costs of a simplified diversion, detention, irrigation control system such as described in the prior discussion. First, as long as there are no major penalties attached to an occasional pollution incident, the least-cost control system would eliminate most of the pollution incidents but would allow extraordinary circumstances to cause some pollution load. The basic reason for not designing a system to handle the extreme or unusual cases is the very low return, in terms of decreased numbers of incidents occurring, to the feedlot operator for his increased costs.

Sizing the detention pond, diversion ditches, and irrigation land areas to accommodate the maximum expected rainfalls, duration of rains, or frequency of rains will increase costs of construction, operation, maintenance, and land. Availability of land for pond purposes and the cost of the necessary added land for maximum protection may be the prime factors considered when sizing a detention pond. However, additional factors that must be considered are the costs of constructing adequate and sturdy diversion ditches, increasing the size of the pump-out system, providing a pump-out system that will operate in the rain, and providing enough land so that irrigation during or prior to a rain will not lead to water pollution.

Even in situations where the detention ponds and diversion ditches are adequately designed to handle maximum expected rainfall conditions, the system can still be an intermittent pollution source because of the land disposal operation. Just as in the case of the other animal enterprises previously discussed, the final test of the system is whether or not the wastes are finally disposed of in a manner that will not allow their eventual movement to a watercourse. If the effluent is placed on the land through irrigation in high concentrations near a watercourse there is little likelihood of complete decomposition before a rainfall washes it into a stream. Therefore, the point of irrigation and the concentration of effluent per unit of land must be carefully watched to avoid intermittent pollution.

Deliberate dumping or releases of animal wastes can also be sources of intermittent pollution. As the terms are used here, dumping deals with a solids waste handling method while releases deal with a liquid or slurry method.

Dumping, although probably infrequent, occurs when the waste materials are collected in their normal semi-solid to solid state and mechanically transported to a disposal site. Unlike the normal spreading of wastes to disperse them, this method dumps the wastes directly into a stream or into a drainage channel to later be washed into the stream. Dumping appeals to some animal enterprise operators because it is an easy means of disposal and is low in cost if returns to nutrient recovery and soil conditioning are discounted.

Releases of liquid or slurry mixtures of animal wastes would normally come from animal enterprises utilizing pit storage areas under the animals. Although there are only a limited number of animal enterprises using pit storage and release systems, they are mentioned here to provide an additional example of intermittent type dischargers. It is recognized that not all pit storage areas are cleaned by releasing the accumulated slurry. Rather, most pits are cleaned by pumping the wastes into special tank wagons for transportation to a disposal area where the wastes are spread on or incorporated into the soil.

The basic advantages of pit storage are temporary storage and the fact that no labor is needed for the cleaning operation during the accumulation period. There are also many disadvantages to pit storage but these will be discussed in a later section of the report.

The temporary storage and periodic release systems are generally used in conjunction with a lagoon or other similar treatment method where the wastes can be biologically degraded. When using this combination system the wastes are released from the pit and channeled into the lagoon. The pit is then washed down and the remaining wastes flushed into the lagoon for treatment. From a water pollution control point of view the major disadvantage with the pit-lagoon combination systems is that a lagoon can be by-passed or not installed at all. As far as the operator of the enterprise is concerned, his prime concern is simplifying the storage and cleaning operation and the disposal of the cleanings with a minimum of effort and cost.

Most enterprise operators consider a lagoon as an unnecessary added cost that they could do without if the wastes can be accommodated by a stream or dispersed far enough down the drainage channel to prevent severe odor or disease problems. Therefore, the pit releases might be direct to a watercourse or to a drainage channel from which they would eventually be washed into a watercourse.

An example of an intermittent release from a covered confinement animal enterprise might be one that stores the wastes outside for some period before they are moved to disposal sites. In this case rainfalls can leach pollutants from the piled wastes and wash them into watercourses. This type of pollution can be extremely deceptive since the leaching process takes out salts, minerals, and nutrients that are invisible to the human eye but very harmful to the watercourse that they enter.

Seldom Dischargers

The discharger that is labeled as seldom in this report is a somewhat special case in that he either has virtually controlled all the wastes discharged from his operation, or he is situated where there is only an occasional climatic phenomenon that can cause his operation's wastes to contribute to water pollution. Some examples of dischargers that fit the seldom category are: feedlots with control facilities sized to handle almost all rainfall situations; lots or waste disposal areas that are well away from streams so that only very heavy rains can cause the wastes to be washed into a watercourse; and systems that are cleaned only once or twice a year but the wastes are disposed of in an area where they can easily be washed into a watercourse.

There is little essential difference in setup between a feedlot classed as intermittent and one classed as seldom. The only differentiating factor between intermittent and seldom is the matter of degree. Therefore, the same sized feedlot could be in either class with only slight modifications of such factors as the size of the detention pond, the lot slope or surface, location of the lot, or the point of ultimate waste disposal.

Feedlots with control facilities sized to handle most climatic conditions can still be occasional sources of water pollution. In such cases the size of the control or treatment facility is usually large enough to handle all but the most severe rainfalls or thaws. However, there are always unusual storms that take place during some years and these storms can cause an overloading of the ponds, lagoons, or diversion ditches. Storms severe enough to cause the system's capacity to be exceeded may occur several times in any given year or may not occur at all in some years.

The following examples of a moderate sized beef feedlot with around 1,000 head on feed at any one time shows the essential characteristics that place a discharger in the seldom category. In this example it is assumed that the lot and necessary additional ground areas were shaped to provide drainage from the lot to the detention pond as well as drainage away from the lot for water from outside sources.

Similiar to the feedlots discussed previously, the categorization of this example lot depends upon how near the design size of the control system is to the maximum runoff condition expected over time. Here again the operator of the feedlot considers the return (amount of pollution controlled) that can be expected for any given investment in control facilities. The investment can range from minor temporary diversion ditches to full scale diversion ditches and a detention pond sized large enough to hold runoff from the heaviest or most extended rainfall or thaw on record for the area. In the first case the discharges occurring after installation of control measures are frequent enough to class the operation as intermittent, while in the latter case there would be no discharge and the operation would fall in the never category.

A discharger with control facilities will usually be in the seldom category if his investment falls in the high end of the control range. In this example the operator has invested at the high end of the range for control facilities. However, he realizes that there are years in which the rainfall intensity of a given storm can create a volume of water greater than the diversion ditches can handle and therefore, some of it can flow across the lot and fill the detention pond at a faster rate than the pond was designed for. He also realizes that there may be other years in which a continuous or nearly continuous rainfall condition will prevail for an extended time period so that the pond will reach overflow stage before conditions permit the pump-out operation to be completed. In each case the frequency of overflow depends upon the maximum expected condition that the system is designed to accommodate.

A feedlot located a considerable distance from any watercourse or a feeding enterprise with a low density of animals per unit of land are other examples of possible occasional dischargers that can be classed as seldom. These situations are similar to those just discussed concerning operation with slightly undersized control facilities. That is, the occasional pollution is dependent upon or caused by unusual weather conditions.

Especially heavy rains or rains of an extended duration can dissolve more wastes and carry them further distances than the light or moderate rains of short duration. The result of such heavy rains is more total wastes being moved to the watercourses. However, in this case, as in the cases of all other seldom and intermittent dischargers, the final test of the system is whether or not the discharges cause water pollution. In other words, it is possible for an enterprise to be subject to an occasional discharge without the discharge resulting in any measurable pollution. If the discharge is never large enough or concentrated enough to create any measurable pollution load, then the enterprise would be classed as never.

Never Dischargers

It may be helpful at this point to give a couple of illustrations of occasional dischargers that are classed as never in order to provide a better understanding of the difference between them and the dischargers labeled as seldom or intermittent. Lots with control systems that are only slightly undersize are seldom subject to an overflow condition which means that several pollution mitigating factors occur before the overflow. First, the major portion of the wastes that can be washed away have already entered the pond and the settleable solids have started their downward movement. Second, more dilution has occurred during the pond collection process. Third, flows in the watercourse have increased. Fourth, the major portion of the rain is over and the amount of overflow is minimal compared with the amount of total runoff that occurred. The effect of all these mitigating factors may be to reduce the waste discharges to a nonmeasurable or insignificant amount.

Essentially the same change in discharge characteristics takes place when heavy rains move greater quantities of wastes further distances. In this case the very things that cause greater movement also mitigate the effects of this movement. That is, high rainfall increases the dilution of the wastes as it moves over long distances, and the longer movement permits more settling and filtering of the wastes. Of course, many factors are involved in whether a runoff situation will cause pollution. Among these factors are: slope and condition of the lot prior to the rain; amount of other surface water entering the same drainage channel; and distance and terrain between the lot and the watercourse.

Summary of Classes of Dischargers

The previous discussion has delineated animal enterprises in terms of their frequency of waste discharge to watercourses. The four classes used in this delineation are: (1) regular; (2) intermittent; (3) seldom; and (4) never. Along with each class term was a definition of the term and several examples of dischargers falling in that class.

For the purposes of this report it is important that the distinction between each class be understood. These differences are important in conceptualizing the animal waste problem and in comprehending the wide variety of opinions on the significance of animal wastes with respect to water pollution.

Estimation of future control needs and the costs of these needs will depend upon understanding these different types of dischargers and what their needs are. It is useless to include a never discharger in any estimation of future control needs and at the same time it is important to decide what the needs of the seldom dischargers are. Solutions to the pollution problems of the intermittent dischargers may very well be different from those solutions applicable to the regular discharger. In other cases the solution may be to bring the intermittent discharger's operation to the same level as the regular discharger and then add the applicable water pollution control solution for regular dischargers to the intermittent operation. In any event, there are undoubtedly other ways to classify waste dischargers, but use of this method will aid in setting up and carrying out future studies of control needs and costs.

This report focuses upon the regular and intermittent dischargers as sources of water pollution because of the high marginal reduction in pollution load possible through abatement of pollution from these sources. Future focus will be on specific types of uncontrolled enterprises to ascertain how they now operate and contrast them with similar enterprises using adequate control systems. Also included will be discussions of experimental control methods or handling methods where applicable information is available.

CATTLE

For the purpose of assessing the water pollution potential of animal wastes, the cattle industry can be divided into three major sectors. First is the beef cow sector where cows are kept for the purpose of producing calves for the feeder market. These calves are sold to the second sector which fattens them to marketable weight and sells them to packers who ultimately market them as dressed beef. The third sector is the dairy industry which keeps cows for the purpose of producing milk and providing replacement milking stock. Although there are specialized operations that do not fit specifically into any one of the three segments mentioned, these segments are broad enough to cover most of the standard operations found in the industry.

A separate review of each of these segments is necessary because of the different ways in which the animals are confined and fed and because of the differing trends that may develop for each segment. Such variable factors as feed, confinement, and changes in numbers of animals affect the amount of pollution, present and potential, as well as the types of controls, changes in handling methods, and treatment methods that may be needed.

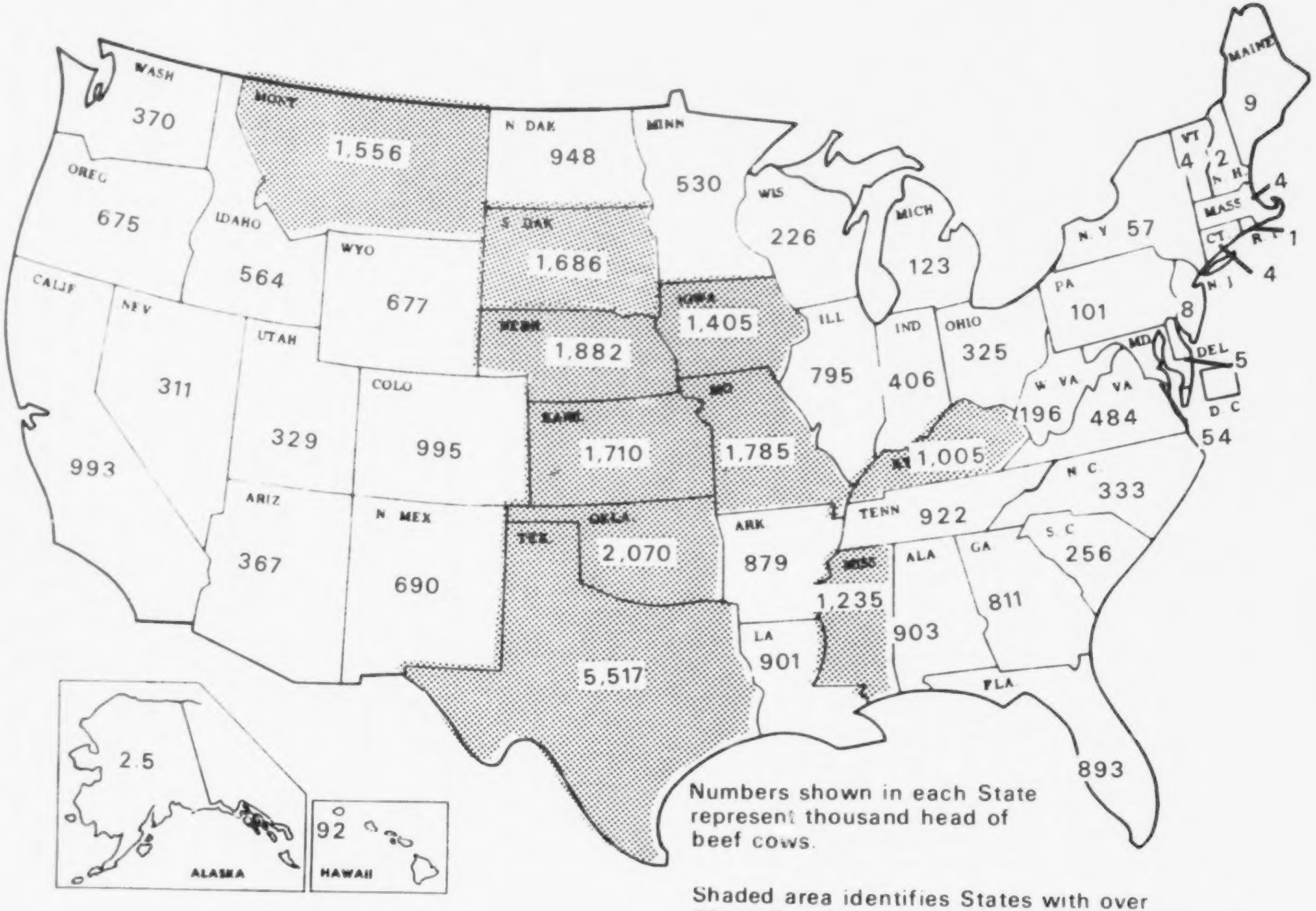
Beef Cows

Beef cow herds can be found scattered throughout the various States, but the greatest production of feeder calves comes from the States of Kansas, Missouri, Montana, Nebraska, Oklahoma, South Dakota, and Texas. Additional heavy production areas are found in California, Iowa, and Mississippi. Map 1, shows the January 1, 1969, concentrations by State of beef cows two years old and older kept on farms. Because these cows are prime sources of feeder calves, this map indirectly indicates the areas of most probable sources of pollution from beef cow operations. However, historical beef cow operations in these areas of heaviest production have tended to be of a range type. Calf production under range conditions means that there are factors operating which mitigate the water pollution potential of wastes produced by the cows and calves.

An important consideration in using range land for calf production is assuring a continuation of the grass supply over the years. Therefore, the cow and calf population per acre are geared to the number of animal units the grazing land can support without damaging the grass. Under most circumstances this concern for the grass results in two major pollution mitigating factors. One factor is a low density of animal units per acre of land. The second factor is the waste retention characteristic of grassland.

Map 1

Number of Beef Cows Two Years Old and Older Kept on Farms, by State--January 1, 1969.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OREG
675
CALIF
993
NEV
311
IDAHO
564
MONT
1,556
WYO
677
UTAH
329
COLO
995
ARIZ
367
N MEX
690
N DAK
948
S DAK
1,686
NEBR
1,882
KANS
1,710
OKLA
2,070
TEX
5,517
MINN
530
IOWA
1,405
MO
1,785
ARK
879
LA
901
WIS
226
ILL
795
MICH
123
IND
406
OHIO
325
KY
1,005
TENN
922
MISS
1,235
ALA
903
GA
811
FLA
893
S C
256
N C
333
VA
484
W VA
196
MD
DEL
5
D C
54
PA
101
N J
8
N Y
57
VT
4
N H
2
MAINE
9
MASS
4
CT
4
R I
1
ALASKA
2.5
HAWAII
92

Numbers shown in each State represent thousand head of beef cows.

Shaded area identifies States with over one million head of beef cows on farms.

As is discussed in more detail in the beef feedlot section, animal density per acre can be misleading when assessing waste potential. That is, up to a critical point additional animal units may add very little to the pollution potential; at the critical point each additional unit adds all its wastes to the potential, while at some point well beyond the critical point each additional unit adds less and less to the potential.

As far as range calf production is concerned, the critical point is never exceeded intentionally because it coincides with the grass preservation policy. Therefore, there will be little accumulation of waste since the biological degradation of the wastes must occur at a rate approximating the rate of waste deposition. By the same token, the grass tends to counteract the waste transport effect of rainfall by slowing and catching the wastes near the point of deposition rather than allowing their free flow to a watercourse. In such situations it is unlikely that water pollution is much of a problem on other than a particular case basis.

On the other hand, there are areas which are increasing their production of beef feeder calves and are doing so in more confined situations. As a result, the animal concentrations per acre of land tend to be much higher, especially during certain seasons of the year. As the concentrations of animals per acre of land increase, the likelihood of water pollution occurring also increases. This increased likelihood of water pollution can result from the concentrations surpassing the critical point or from a significantly higher critical point because of extremely favorable pasture conditions.

Based on the foregoing overview of the beef cow industry, it appears that we need to concentrate our efforts on projecting the trends of the industry as to location and concentration of animals. This information, coupled with the results of studies under way on determining the amount and characteristics of runoff that occur in pasture situations or in concentrated confinement situations, will provide two parts of the base necessary for estimating the cost of controlling water pollution from beef cow herds. Other necessary parts of the base are types of control measures applicable and their costs.

In light of the small likelihood of beef cow herds being the source of significant water pollution on a broad scale at this time, the emphasis on determining costs associated with water pollution control should be placed on some other segment of the cattle industry for the near future. This is particularly true since the research being done in the other animal areas can be transferred on a case-by-case basis to handle individual pollution problems in the beef cow area.

Fat Cattle

The fat cattle industry is a major source of beef for human consumption. Fat cattle can, for our purposes, be considered as coming from two sources--concentrate fattened and grass fattened. Of the approximately 34 million head (Figure 6) of cattle and calves now slaughtered annually, around 80 percent come from fat cattle operations. Out of the estimated 28 million head of fat cattle slaughtered annually in recent years, about 23 million were marketed out of feedlots. The remainder, although not a precise estimate, can be considered as an indicator of the grass fattened cattle.

Grass fattened cattle, as the name implies, are those that are raised to market weight under pasture or range conditions where the main feed is grass with supplemental feed fed only as required. Concentrate fattened cattle, on the other hand, are usually fed in confined areas where the concentration of animals is such that grass cannot grow or is too sparse to provide adequate feed for the animals. In such cases the cattle must depend upon feed brought in by the operator of the feedlot. The feed brought in may be a concentrate such as corn, maize, milo, or similar product. In addition, there may be other concentrates, proteins, or minerals added to or mixed with the basic ration. The main objective is to use a ration that is least costly in the context of the particular feeding operation. This often means a ration that produces a high rate of gain per animal and consequently a relatively rapid turnover of animals through the lot.

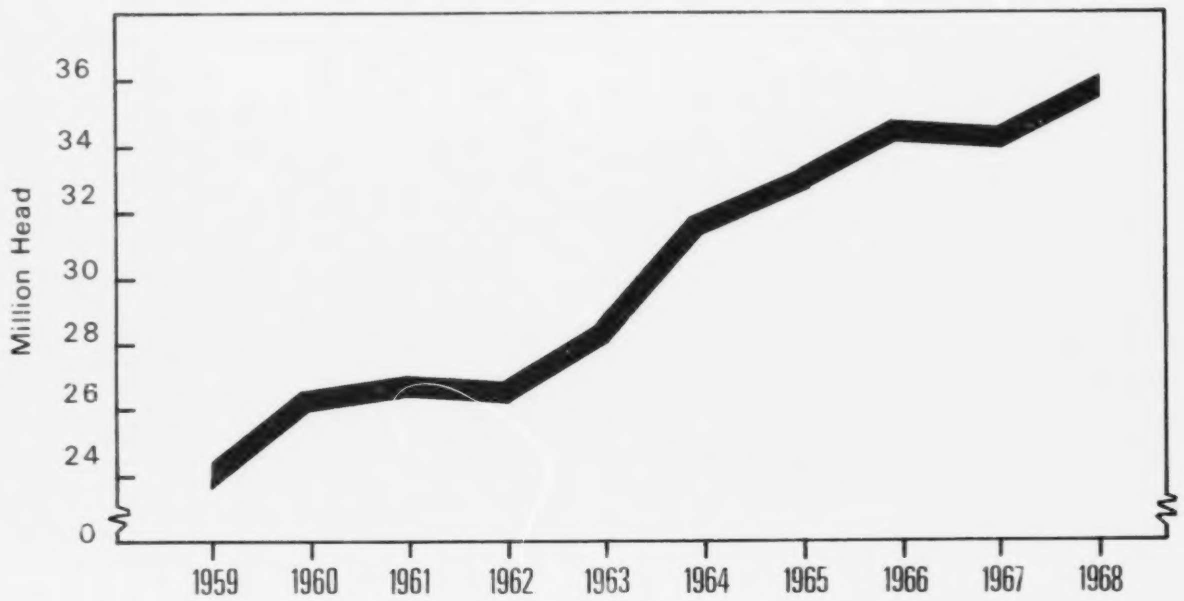
The distinction between grass fattened cattle and concentrate fattened cattle is important to this report only because of the differing potential for water pollution that each type of operation poses. The grass fat cattle generally can be considered as minimal sources of water pollution. The remainder of this section is devoted to a detailed discussion of the pollution potential of various types of fat cattle operations. The schematic diagram in Figure 7 shows the breakdown of the operations that will be discussed in light of each segment's water pollution potential.

Animal Wastes That Cause Water Pollution

At this point it may be helpful to discuss the general aspects of water pollution resulting from climatic factors acting upon uncovered animal fattening operations. Since these climatic factors affect all types of uncovered animal raising operations, the points discussed here are also referred to in other sections of the report. However, the major source of potential pollution from animal wastes is the cattle fattening industry, therefore, these general aspects are most appropriately discussed at this point.

Figure 6

Cattle Slaughter, 1959 through 1968.



SOURCES: Livestock and Meat Statistics--Supplements for 1967 and 1968 to Statistical Bulletin No. 333, U.S. Department of Agriculture, Economic Research Service, Statistical Reporting Service, and Consumer and Marketing Service, Washington, D.C.

Schematic Drawing of the Components of Fat Cattle Operations that Affect the Water Pollution Potential of the Animals.

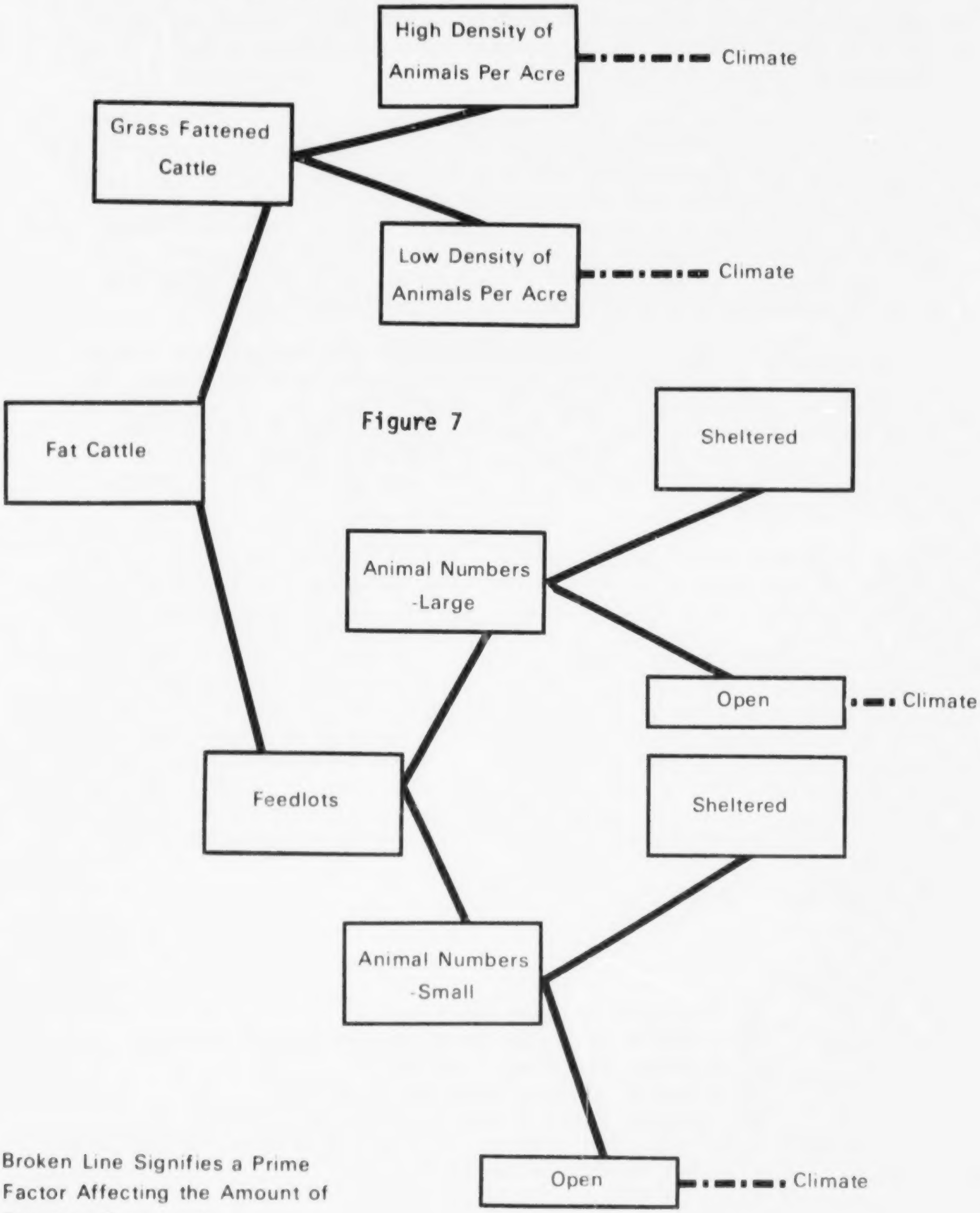

High Density of Animals Per Acre
Climate
Grass Fattened Cattle
Low Density of Animals Per Acre
Climate
Fat Cattle
Sheltered
Animal Numbers -Large
Open
Climate
Feedlots
Sheltered
Animal Numbers -Small
Open
Climate

Figure 7

Broken Line Signifies a Prime Factor Affecting the Amount of Pollution Generated.

It can be said, from a water pollution prevention standpoint only, that this report's concerns are the amounts and characteristics of animal wastes that reach watercourses. Although, there are other mitigating factors, for our purposes this general assumption is adequate.

In most instances, cattle fattening enterprises can be categorized within the ranges of intermittent, seldom, and never. A large number fall into the intermittent category but there is no estimate of the actual numbers that fall into any of the categories at this time. As more information is accumulated regarding runoff from confinement areas under varying circumstances and as inventories of the animal enterprises become available, it will become possible to estimate the number and size of the enterprises falling in each category.

Climatic factors such as precipitation and temperature are the prime causes of intermittent type discharges. In other words, rain falling on unsheltered animal confinement areas causes a runoff of the wastes from the areas. Likewise, temperature has an effect because it can solidify the wastes and prevent their runoff or it can prevent their absorption into the soil and thereby permit future runoff to occur.

A general formulation of the water pollution potential of any given animal enterprise would show that the potential is related to many factors interacting with each other. The actual pollution is then a result of outside factors acting upon this potential. The factors affecting the potential are: (1) numbers of days the animals are confined; (2) daily quantities of wastes produced per animal; (3) number of animals; (4) characteristics of the wastes; (5) amount of daily degradation of the wastes; (6) amounts of waste removed by runoff; and (7) amounts of waste removed by cleaning operations. A simplified formula such as the following formula which measures the pollution potential in terms of population equivalents can be used to illustrate the interaction of the seven aforementioned factors.

$$P = E_n \qquad (A_c T_c) - \frac{(C_r + R_r)}{\quad}$$

Where:

T_c = Numbers of days confined
W_a = Pounds of wastes produced per animal per day
A_c = Number of animals confined
R_r = Pounds of waste removed by runoff
C_r = Pounds of waste removed by cleaning
E_n = Population equivalent, net waste quantity produced per animal daily where;

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A_c = Number of animals confined
R_r = Pounds of waste removed by runoff
C_r = Pounds of waste removed by cleaning
E_n = Population equivalent, net waste quantity produced per animal daily where;

$$E_n = \frac{(W_a \cdot O_d) - (D_o)}{0.17}$$

Where:

O_d = BOD per pound of waste
D_o = Degradation or satisfied daily BOD (estimated)
0.17 = Standard 5-day per capita oxygen demand of domestic sewage
P = Total water pollution potential in population

In uncomplicated terms, this formula determines the BOD of an animal's daily wastes and deducts from that the estimated average daily decomposition per animal (in BOD) to arrive at a net oxygen demand per animal per day. This net oxygen demand is then converted to a population equivalent and used to convert the net animal days to a population equivalent for the entire period of wastes accumulation. Net animal days are computed by multiplying the number of animals confined by the number of days in confinement and deducting from the result the number of animals equivalent to losses in waste resulting from runoff and cleaning operations. In other words, the BOD of the total wastes produced minus the BOD in losses due to degradation, runoff and cleaning yields a net wastes available figure in terms of oxygen demand. The net wastes figure is then converted to a population equivalent which is the maximum potential pollution of the confinement area expressed in terms of BOD equivalent of human wastes.

In summary, then, the maximum water pollution potential is related to the waste production per animal, maximum number of animals in the confinement area, days confined, frequency of cleaning, climate, waste degradation, and waste characteristics. On the other hand, actual pollution will be affected by factors such as temperature, rainfall, surface area of confinement pen, slope of the area, texture and materials mixed with the wastes, type of lot surface, and management practices. In other words, actual pollution will not be equivalent to potential pollution under most conditions. An individual exception to such a statement would be a lot where the surface had been recently cleaned and a flushing rain cleans the lot surface depositing the entire amount of accumulated wastes in a watercourse. However, over a longer-run period of time the actual quantity of animal wastes reaching watercourses will always be substantially less than the potential quantity.

On a case-by-case basis it is the amount of pollutant that actually reaches a watercourse that determines the extent of the pollution. However, even in these cases there is a certain amount of runoff that carries pollutants in concentrations too small to have a measurable pollutional impact on the water. That is, during certain rains the dilution factors of the rainfall and the receiving waters offset any pollutants carried from the lots.

On a gross basis the amounts of pollutants reaching watercourses are not measures of actual pollution but only measures of the upper limits and, at best, indicators of the problem. Conversely, on a case-by-case basis the amounts of pollutants reaching a watercourse can be related to stream flow and other dilution factors to obtain a good estimate of pollution potential. Despite these limitations it is important to understand the general behavior of animal wastes during runoff conditions in order to broadly categorize the various sizes, types, and locations of animal operations. The runoff behavior of the wastes will also have an effect upon the costs of containment or treatment facilities that might finally be required.

Factors affecting runoff of potential wastes

Many of the factors affecting the amounts of wastes removed from the total potential wastes contained on a feeding area during a specific runoff condition have been mentioned previously. They include such diverse items as: lot slope; climate; lot location; general terrain; lot surface; waste characteristics; and management practices. Although there is some empirical information on wastes runoff, there is a decided lack of information on the runoff under varying combinations of the factors just enumerated. However, studies under way, such as the ones sponsored by FWPCA at Texas Technological College; Kansas State University; and North Carolina State University, will add significantly to the body of knowledge on wastes runoff.

The present state of knowledge on feedlot runoff is adequate to use in making some general statements regarding the runoff potential and in categorization of the animal feeding operations. For example, as cattle density per unit of land increases past a critical point, runoff pollution per animal decreases. Also, cleaning may very well increase the actual pollution contained in runoff from the lot, depending upon the season, lot surface, and frequency of cleaning. Actual runoff potential from a given lot over time increases to a certain point and then levels off with no further increase in potential for actual runoff during the remainder of the accumulation period. Each of the previous statements is based upon the simple premise that once wastes have accumulated to a certain point, no runoff will occur during light rains and runoff occurring during heavier or longer rains will only remove some upper portion of the accumulated wastes.

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Figure 8 depicts a rough approximation of how the concentration of animals per unit of land affects the average amount of pollution per animal that is washed from a confinement area by a given amount of rainfall. Reading the curve from bottom to top the general interpretation is that a certain number of animals must be present before any pollution occurs. Then, as the density nears the critical point, the pollution level rises rapidly followed by an approximate unit increase for each added animal or decreased land area until the vertical accumulation point is reached. From the runoff depth point and upward, in terms of animal density, the average pollution per animal decreases because only a maximum amount will erode from a given sized lot during any specified rainfall. The curve shown in Figure 8 is not meant to be used for comparative purposes and is not drawn to scale so that no inferences should be made from the curve as to specific relationships between numbers and quantities. The figure's sole purpose is to give some visual idea of how animal density affects pollution. The following explanation of the terms used in Figure 8 also provides the reasoning that went into development of the visual representation.

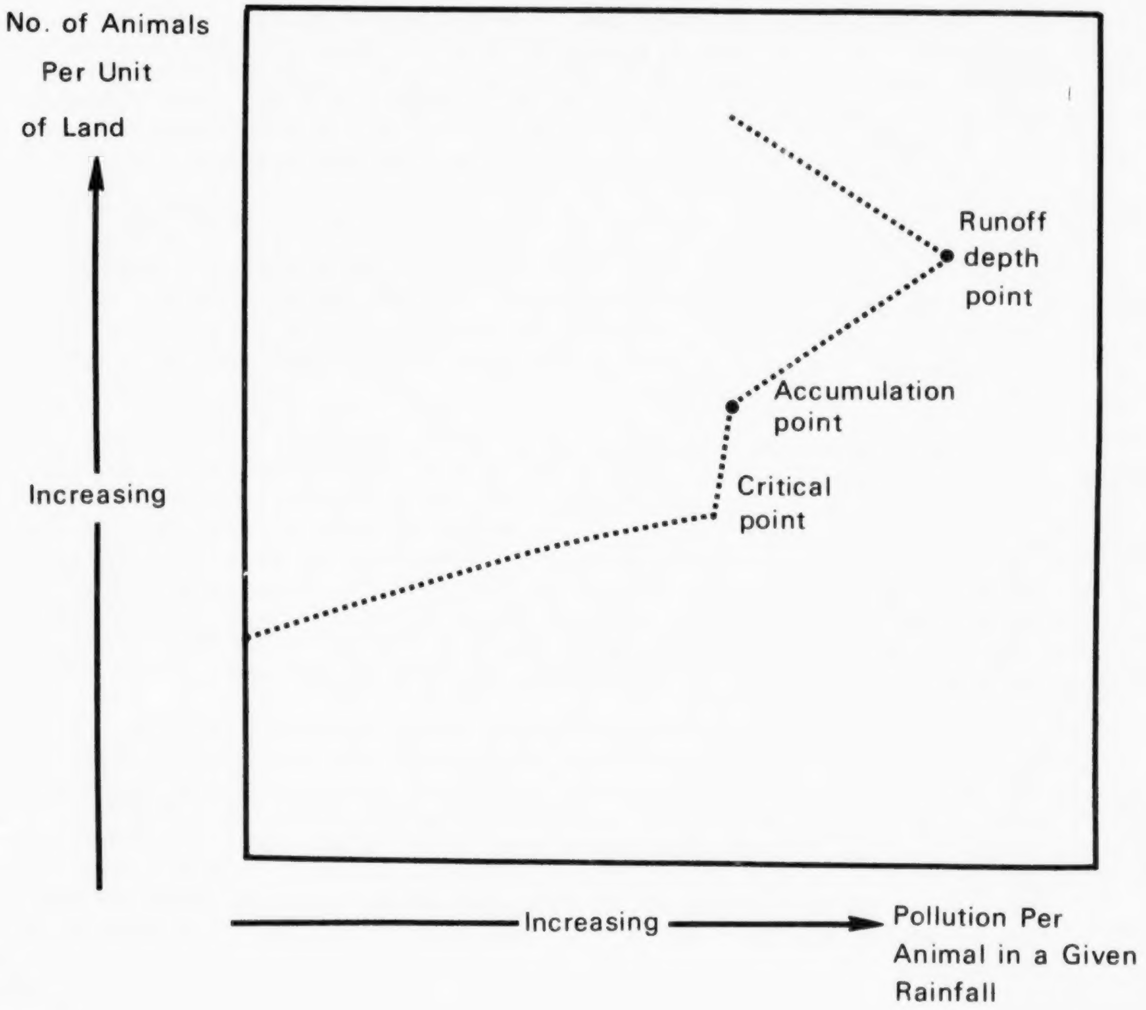
Reason alone tells us that one animal standing in the middle of a 100 acre pasture is not a source of water pollution. The basic reason behind this conclusion is that most of the waste would not be washed out of the grass and into a watercourse. Additionally, even if the animal was very close to a stream, the dilution of the waste by all of the water rushing off the entire 100 acres would render the pollution insignificant, if measurable.

Extention of this reasoning leads to the conclusion that as the density of animals increases, a point will be reached where the pollution is measurable. As animal concentration continues to increase, the effectiveness of grass as a trap and filter decreases. When the densities approach the critical point no cover remains on the soil. Thus, the trapping and filtering effect on the grass has disappeared. From the critical point until a vertical accumulation of undecomposed wastes begins, increasing densities raise the total pollution concentration but have little effect on the average quantity of pollutant per animal.

The vertical accumulation of wastes is an important point to understand since it is this factor that causes the average pollution per animal to rise faster than the additional concentration of animals would indicate. That is, in a situation where animals are added to a specified size feedlot, each additional animal would not be expected to add to the average amount of pollution per animal. However, when the wastes are allowed to accumulate, the amount of accumulated wastes can be washed out by a rainfall thereby raising the average amount of pollution.

Figure 8

Graphical Description of Pollution Per Animal Contained in a Given Rainfall Runoff.


No. of Animals Per Unit of Land
Increasing
Runoff depth point
Accumulation point
Critical point
Increasing
Pollution Per Animal in a Given Rainfall

Any given amount of rainfall on the same lot under the same conditions will remove about the same quantity of wastes from the accumulation. Therefore, when accumulated wastes reach the maximum depth of runoff erosion, additional accumulation will not add to the amount of waste of pollutants carried away during a given rainfall. As a result, once the runoff depth point is exceeded the average pollution per animal decreases as the density of animals increases. The vital concept that applies to this discussion is that the runoff depth point is for a given rainfall and that heavier or extended rainfalls have deeper runoff depth points and vice-versa. Other factors affecting the runoff depth point are temperature, lot condition, slope of the lot, intensity of the rainfall, and type of wastes.

Data collected, analyzed and published by Miner et al. 1/detailed the wastes characteristics of feedlot runoff and discussed the factors affecting runoff concentrations. It was found, for example, that the strength of the runoff from the experimental lots increased with increasing temperature, increasing moisture content of the lot, and decreasing rainfall intensities. Other variables, although possibly relevant, were not tested in this limited experiment.

The preceding discussion of the effect of rainfall on animal wastes in an unsheltered situation leads to several conclusions abut fat cattle operations as shown in the schematic drawing of Figure 7. An initial conclusion is that range fattened cattle represent a much smaller pollution problem than feedlot cattle, both in numbers and in actual runoff pollution per animal. Also, as density of animals per acre increases in a range situation, the likelihood of actual pollution occurring also increases. Finally, it can be concluded that a more detailed analysis of the numbers of animals and their locations on a broad climatic base can be productive in developing estimates of actual pollution from which estimates of control costs can be formulated.

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1) Miner, J.R., Fina, L.R., Funk, J.W., Lipper, R.I., and Larson, G.H., "Stormwater Runoff from Cattle Feedlots". Management of Nine Farm Animal Wastes (Proceeding National Symposium, May 5,6, and 7, 1966) American Society of Agricultural Engineers, St. Joseph, Michigan.

GRASS FATTENED CATTLE

Although there are several million cattle fattened annually under pasture or range conditions, the wastes produced by these animals have a minimal water pollution potential. The critical points, as discussed in the prior section, are seldom exceeded in grass fattening operations. That is, the animal densities per acre are usually light enough to preclude any water pollution unless the animals are in direct contact with the stream. Even in cases where the animal densities approach the critical point there is some effective filtering and trapping of the wastes by the grass. Additionally, there is little undegraded material accumulating to be washed off in slug quantities.

Low Density

Grass cattle fattening operations that have animal densities well below the critical point do not require early emphasis on estimation of their water pollution control costs. The basic problem with the low density operations is assuring that the animals are not in direct contact with the water. In almost all cases the control measures and their costs will be unique and general cost estimates for keeping cattle from water contact will not be applicable.

Some operations may require considerable fencing to keep the animals from the water and may also require supplemental water supplies for the cattle. The control costs in these cases would be fencing costs plus water piping, storage, and pumping costs. In other cases, there may be only limited access to the water and fencing would be a minor cost while water provision might be a more substantial cost. In any case, as inventorying and more refined assessments of water pollution under range conditions become available, there will be a stronger base from which to estimate the water pollution control costs associated with such operations.

High Density

Grass cattle fattening operations with heavy animal concentrations are more likely sources of potential water pollution than are the low density operations. As the animal densities of the operations approach the critical point, potential pollution increases along with the probability of actual pollution occurring. This report is, of course, concerned with the actual pollution aspects of the fattening operations although potential pollution can be an indicator of the magnitude and the location of actual pollution.

High density operations have actual pollution problems similar to the low density operations in those situations where the animals are in direct contact with the water. Additionally, the high density operations have more wastes per acre subject to runoff and as the densities approach the critical point, these wastes have less and less grass available to trap and filter them.

There is somewhat of an anomoly in discussing densities since the densities will vary largely according to the ability of the land to support the animals. Therefore, increasing densities do not necessarily lead to increased pollution. Rather, the densities must always be related to their critical point before any conclusions about their potential or actual pollution can be drawn. High densities on grasslands with high critical points may not add significantly more to water pollution than low density operations on grasslands with low critical points.

As far as grass cattle fattening operations are concerned, their animal densities are closely related to climate. In order for high densities to be practical the rainfall must be adequate to support a heavy growth of grass. However, the reverse is not necessarily true. That is, an area producing lush growths of grass may or may not be an area supporting large numbers of grass cattle fattening operations.

Broadly speaking then, water pollution from high density cattle operations is influenced by interaction of the following factors: (1) higher densities resulting in more total wastes production per unit of land; (2) heavy grass growths are required to support the high animal density; (3) adequate rainfall is required to produce the lush grass; (4) lush grass growths tend to trap and filter more of the wastes during runoff conditions; (5) higher rainfalls tend to wash more of the wastes from the land but they also provide some additional dilution of the wastes. It is easy to see that the interaction of these factors prevents any purely judgemental assessment of the amount of actual water pollution occurring as a result of high density grass cattle fattening operations. However, the mitigating factors are important enough to provide a base for the conclusion that the amount of water pollution from these animal sources, although not quantifiable at this time, is much less than that from sources such as feedlots where the critical animal density point has been surpassed. Like the low density operations, better estimates of the actual pollution resulting from high density operations can be made after work is completed in measuring runoff and stream monitoring under varying pasture loading conditions.

In terms of overall importance in the total water pollution picture, high density cattle fattening operations must rank above the low density operations. However, a major thrust of the water pollution control efforts should not be directed at this segment until the more direct and larger pollution sources have been located and controlled. This is not to say that the individual cases of water pollution should not be located and controlled whenever possible. Rather, it means that on a national scale with limited resources, these resources should be used to attack general problems with the greatest potential for high marginal reductions in pollution loads. Then, as these primary pollution sources are controlled, the early ongoing research on the lesser problem areas can be brought to bear on solving such problems at a minimum cost.

CONCENTRATE FATTENED CATTLE

Cattle fed in the limited confinement feedlot areas annually produce billions of pounds of wastes. The handling (removal and disposal) of these wastes presents the feedlot operators with major labor, equipment, and logistical problems. Additionally, these wastes represent potential water pollution sources of a serious nature and magnitude.

Actual observations have shown that many feedlots are located on or very near to streams. The close proximity to watercourses and the slope of these lots force any significant rainfall to carry heavy slug loadings of BOD, COD, and other harmful components of the wastes into the streams. In the midwestern areas where manure collects on the lots during the winter when little decomposition takes place, the slug loads can be especially heavy during the spring rains and thaws. Although quantities or frequencies of actual pollution from animal wastes are not known, evidence of such pollution and the damages it can do may be found in the number of reported fish kills attributed to animal wastes pollution.

Table 1 shows the number of reported fish killed during the year 1964 through 1968 as a result of animal wastes entering watercourses in lethal concentrations. Although these figures probably do not tell the complete story, they are useful in showing that animals can and do contribute to water pollution under certain conditions. Since the fish kill figures shown in Table 1 represent only reported kills that were traced to animal wastes pollution, the true number of kills is likely much higher. Also, these figures provide no indication of the amount of stream degradation which occurred but did not result in outright or traceable fish kills.

Besides the obvious pollutional hazards of feedlot wastes such as fish kills, it has been demonstrated (Miner et. al.) that feedlot runoff is a source of high concentrations of bacteria. Since bacteria are normally considered as indices of sanitary quality, their presence in high concentrations can result in that particular section of water not meeting the accepted water quality standards.

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Table No. 1 -- Number of reported fish kills and total number of fish killed as a result of manure, silage, or feedlot drainage, 1964 through 1968.

	Number Reporting	Number of fish killed
1964	26	1,156,885
1965	25	616,882
1966	34	1,040,993
1967	37	1,268,137
1968	19	35,238

Source: Pollution Caused Fish Kills, Federal Water Pollution Control Administration, United States Department of the Interior, Washington, D. C.-- 1964, 1965, 1966, 1967, 1968.

Number of Feedlots

The number of feedlots marketing cattle in 1968 came to 208,596. These feedlots marketed over 23 million head of cattle, with almost half of the marketings coming from lots with capacities of over 1,000 head. In terms of our definition, almost all feedlots have animal densities that meet or exceed the critical point. In fact, most of these lots will exceed the accumulation point as well as the maximum runoff depth point. Therefore, feedlots are likely sources of water pollution deserving further analysis and enumeration based upon such analysis.

Discharge Frequency

The frequency of discharges from feedlots can, in most cases, be categorized as seldom to never. The remainder of the cases generally fall into the intermittent category although it is possible to have some feedlots regularly discharging wastes.

Across the country the prime factor affecting both frequency of animal waste discharges from feedlots and the amounts of such discharges is climate. Of course, for any particular lot the effect of climate can be modified by management decisions, lot location, and the general topography of the lot and surrounding areas. In general, however, climate is the major factor to consider in determining needed waste control facilities and is, therefore, an indirect determinant of costs.

Climate

Climate basically affects the runoff from a feedlot through an interrelationship of temperature and precipitation. However, climate also influences the number of animals fed by a single enterprise, concentration of animals within a feedlot, location of the lot, and the amount and type of shelter provided for the animals. All of these factors influenced by climate also affect the amount of runoff that can be expected.

With some variation based on intensity and temperature, runoff from a feedlot varies directly with the amount of precipitation. That is, the more precipitation, the more runoff that can be expected. Even precipitation in the form of snowfall can cause runoff during thawing conditions.

For any specified rainfall, the concentration of wastes and therefore the total amount of wastes removed from the lot varies inversely with the intensity of the rainfall. High intensity rains create less total pollution than low intensity rains depositing the same volume of precipitation. The effect of temperature on runoff is basically found at the extremes of hot and cold. If the temperature causes the wastes on the feedlot to be in a semi-frozen to frozen state, the waste runoff is retarded significantly. Similarly, if the temperature is high enough along with proper moisture and wind conditions, to promote rapid drying on the feedlot surface, the wastes dry out and become packed into a solid state resulting in decreased runoff from any given amount of rainfall. On the other hand, frequent rains, humid conditions, and high animal densities tend to keep the lots moist and thereby increase the amount of wastes runoff from a given rainfall. The increased runoff and concentration of wastes in the runoff result from a lower absorption capacity of the wastes on the lot and because the wastes are in a semi-liquid state which eases their pick-up by the runoff water.

The preceding summary of the major effects of climate on runoff from feedlots and the amount of wastes contained in such runoff is not meant to be at all inclusive. Rather, it serves to show that groupings of feedlots by major climatological variations have relevance in assessing the overall water pollution control problems associated with feedlots.

Management decisions concerning the number of cattle to feed, animal densities to maintain, type of shelter to be provided, and the location of the feedlots are largely influenced by climatic factors. Favorable climates, particularly those without extreme cold or high precipitation levels, are conducive to large scale feedlot operations. In the favorable climates the most important limiting factors affecting size are feed supplies, availability of feeder animals, and to some extent, high temperatures.

Cold areas with high precipitation levels are especially unfavorable to the operation of large-scale feedlots. During cold weather the precipitation may well be in the form of snow or sleet. In either case, both the cold and the precipitation place added stress on the animals as well as on the men and equipment. The result of such added stress is lower gains per animal relative to feed consumed, higher death losses, fewer animals handled per man, and increased equipment costs. Overall, the greater demands on management and increased costs in such situations usually restrict the size of the feedlot operations.

The number of animals per unit of land is also influenced by climate. In the areas of heavy precipitation, animal densities on unsurfaced lots must be decreased in order to maintain reasonable lot conditions. Heavy animal densities during wet periods, especially during spring thawing conditions, can create a quagmire of mud and wastes in the feedlot. Conversely, animal densities can be quite heavy in dry climates without creating undesirable lot conditions.

Poor lot conditions increase animal health problems, adversely affect feeding efficiency, and add stress to men and equipment. In order to overcome the adverse effects of poor lot conditions the feedlot manager may decrease the animal densities or provide a hard surface for the lot. In either case the costs compared with dry areas are increased and all of the other undesirable effects of climate remain.

Earlier discussions on the amounts of runoff under varying animal densities concluded that high densities decreased the average actual pollution potential per animal. That is, after the runoff depth point is passed in vertical accumulation, the average runoff per animal decreases. Under such a situation a seemingly obvious solution for reducing water pollution from animal wastes is to increase the concentrations of animals per unit of land. However, the general management practice in humid climates would be almost directly opposite to this solution. In other words, animal densities, because of basic management considerations, vary inversely with precipitation which means decreasing densities at the time when runoff conditions would indicate a need for increasing densities.

Lot locations and shelter provided depend upon climatic conditions intertwined with considerations on the number of animals raised and the animal densities. A new large-scale feeding enterprise with a free choice of locations will tend toward the favorable climate areas. In such cases, any shelter provided will probably be in the nature of shade from the sun rather than protection from cold or snow. Sun shelter usually does not affect pollution potential since it is a minimum cost shade shelter rather than a sturdy roof with load bearing or water shedding capabilities.

In direct contrast to shade shelters in hot climates is the cold climate shelter with protective roofing of load-bearing capabilities. In these circumstances proper drainage of the covered areas can significantly decrease wastes runoff from the feedlot area. In fact, newer technology utilizing covered areas with slotted floors and pit storage of the wastes under the floors completely eliminates runoff from the feedlot. Whether or not this new technology is adopted depends upon several factors. Running counter to adoption of such a system is the high initial investment in facilities and a relatively high investment in liquid-manure handling equipment. However, on the positive side for the colder climates there is a lessening of stress on animals, men, and equipment. Also, this system provides a positive water pollution control solution if the liquid wastes are disposed of properly. In the milder climates the covered system's major advantages are pollution control, a simplified wastes handling method, some decrease in land requirements, and possibly reduced nuisance problems.

Even after the feedlot location has been chosen by general climatic region and available land, management must locate the lot at a specific point. Climate is again a factor in that the choice location should provide good drainage from the lot along with some shelter if needed. Often, good drainage from the feedlot creates a water pollution hazard of the wastes on the lot. As far as natural shelter is concerned, its main effect on water pollution potential is the lessening of any need for the types of covered operations that reduce or preclude runoff.

The foregoing discussion indicates that water pollution resulting from feedlot animal wastes is largely dependent upon a combination of climatic factors and their effect on management decisions. Basically, without precipitation there would be no runoff and, therefore, no water pollution from feedlots. The frequency and amounts of precipitation are, therefore, prime factors to consider when assessing potential water pollution situations. In addition, the effects of precipitation can be modified directly by temperature; e.g.; freezing or drying of the wastes, or indirectly by the effects of climate on management decisions. That is, management decisions regarding the location of a feedlot can change the lot's drainage pattern or, more broadly, management can locate the lot where precipitation and therefore runoff is minimal. Other management decisions influenced by climatic conditions that can affect runoff are: the amount and type of shelter provided, density of animals on the land, and the number of animals raised. Since climate plays such an important role in the assessment of water pollution potential from feedlot animal wastes, the following section is devoted to grouping the known factors about the feedlot industry according to geographic area and general climatic conditions.

Major Feeding States

The 32 major feeding States accounted for over 23 million head of cattle marketed from feedlots in 1968. About 20.2 million head were marketed from feedlots in the 14 States with the largest marketings from feedlots in 1968. (See Map 2.) It is, therefore, apparent that the feedlot cattle operations are concentrated in relatively few States. Even more important from a water pollution standpoint is the fact that cattle feedlots are generally more heavily concentrated in specific sections of these States. As a result, the pollution potential, both in total magnitude and in the cumulative effect along a watercourse, is very high for such localized areas.

Feedlot Capacities

Feedlots with capacities of 1,000 head or over accounted for almost half of the total cattle marketed out of feedlots (Table 2.) in 1968. However, by virtue of the capacities of these larger feedlots, they only account for about one percent of all feedlots. In other words, the 2,080 lots of 1,000 head or over capacity marketed almost 11 million head of the slightly more than 23 million head marketed from all feedlots in 1968. The other 206,516 feedlots of less than 1,000 head capacity accounted for the remainder of the cattle marketed from feedlots.

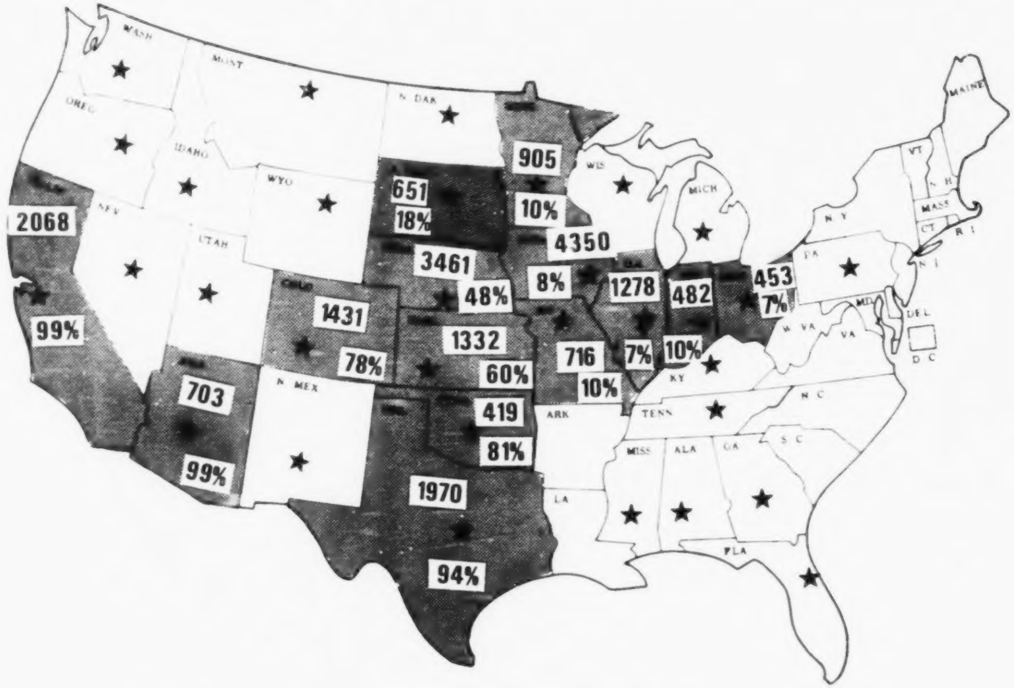
Almost 90 percent of the cattle from feedlots raising over 1,000 head come from ten States west and south of the Missouri River. (See Table 3 and Map 3.) These ten States account for 1,522 of the 2,080 feedlots reported to have had a capacity of 1,000 head or more in 1968. On the other hand, ten midwestern States, including an overlap of Kansas and Nebraska previously included in the large lot category, account for the bulk of the small feedlots and cattle marketed from them. From Map 4 it can be seen that these ten States account for 185,264 lots out of the total in this under 1,000 head size group of 206,516 and for about 10.6 million out of a total of 12.2 million head marketed from this smaller group.

Many of the lots of under 1,000 head capacity are extremely small. The average size of lots under 1,000 head in the five States with the largest number of feedlots is only 65 head (See Table 4.) and the average of the ten States shown on Map 4 is 57 head.

The larger feedlots with capacities of 1,000 head and over had an average of 5,203 head marketed out of them in 1968. However, the distribution of marketings varied considerably. For the top ten States, ranked by total marketings in 1968, the average size of marketing from the over 1,000 head capacity lots ranged from 2,090 head for Iowa to 11,443 head for Colorado. (See Table 5.)

Map 2

Number of Cattle Marketed out of all Feedlots by the Fourteen States with the Largest Marketings in 1968, Location of Major Feeding States, and Percent of Cattle Marketed from Feedlots with Capacities of 1,000 Head and Greater.


WASH
MONT
N. DAK
OREG
IDAHO
WYO
NEV
UTAH
N. MEX
WIS
MICH
N. Y.
VT
N. H.
MAINE
MASS
CT
R. I.
N. J.
PA
MD
DEL
D. C.
W. VA
VA
KY
N. C.
TENN
S. C.
ARK
MISS
ALA
GA
LA
FLA
2068
99%
703
99%
1431
78%
651
18%
3461
48%
1332
60%
419
81%
1970
94%
905
10%
4350
8%
716
10%
1278
7%
482
10%
453
7%

★ Indicates a major feeding State.
Shaded areas indicate the fourteen States with the largest cattle marketings in 1968.
Top number shown in each State refers to thousand head of cattle

Percentages shown refer to the percent of cattle marketed from feedlots with capacities of 1,000 head and greater.

Total cattle marketed out of feedlots in 1968: 14 States-- 20,219,000 head; 32 States 23,040,000 head.

Table 2. Number of cattle marketed by size groups and number of feedlots in each size group--1968.

Lot Size	No. of Cattle Marketed	No. of Feedlots
(Head)	(1000 Head)	
0-- 999	12,217	206,516
1000-- 1999	1,214	967
2000-- 3999	1,434	522
4000-- 7999	1,970	316
8000--15999	2,499	176
16000--31999	2,491	80
32000-- & up	1,215	19
Total from all lots	23,040	208,596
Total from lots over 1000 head	10,823	2,080

Source: Cattle on Feed, January 1, 1969, Statistical Reporting Service and Crop Reporting Board, United States Department of Agriculture, Washington, D.C.

TABLE 3

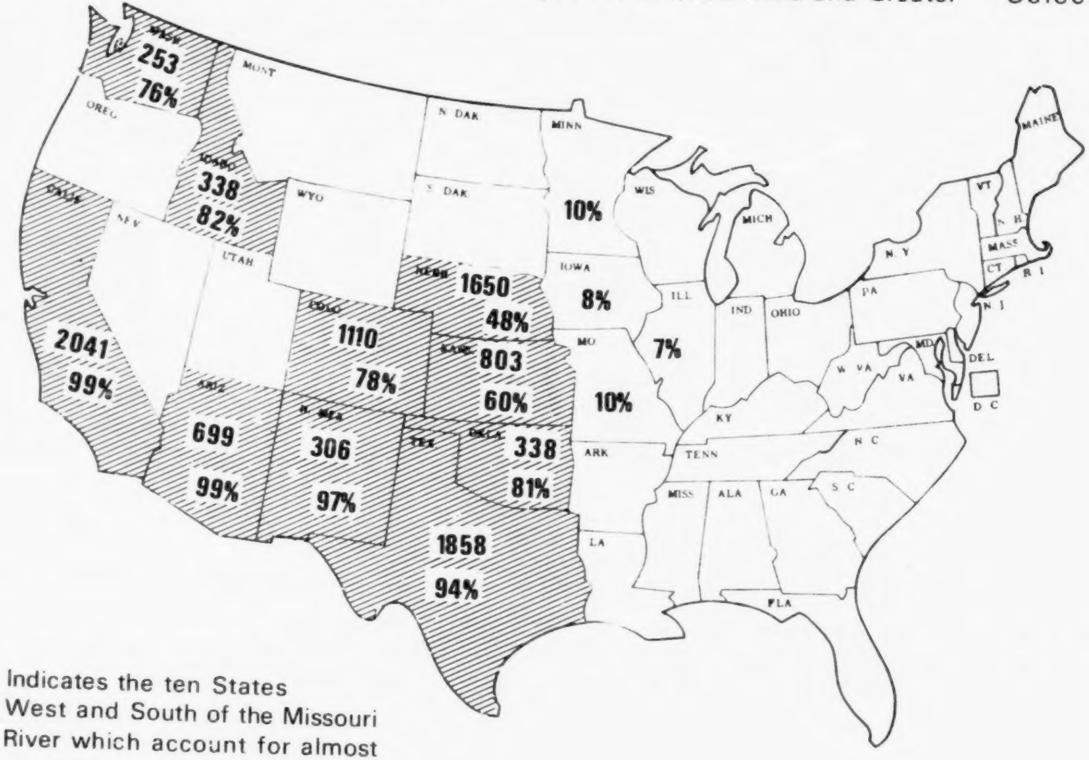
Number of cattle marketed and number of feedlots by top ten States in terms of the number of cattle marketed from feedlots with over 1000 head capacity--1968.

State	Lots over 1000 head		Lots under 1000 head		Percentage of total cattle marketed from lots over 1000 head
	No. of lots	No. of cattle marketed	No. of lots	No. of cattle marketed	
		(1000)		(1000)	
California	288	2041	203	27	99
Texas	294	1858	1300	112	94
Nebraska	463	1650	21215	1811	48
Colorado	97	1110	1263	321	78
Kansas	100	803	11400	529	60
Arizona	68	699	9	4	99
Iowa	165	345	45835	4005	8
Oklahoma	54	338	1400	81	81
Idaho	81	338	658	74	82
New Mexico	40	306	36	10	97
TOTAL	1650	9488	83319	6974	

Total cattle marketed from all feedlots 23,040,000 head
Cattle marketed from lots over 1000 head---10,823,000 head.

Map 3

Number and Percentage of Cattle Marketed from Feedlots with Capacities of 1,000 Head and Greater --Selected States, 1968


WASH
253
76%
OREG
IDAHO
338
82%
MONT
CALIF
2041
99%
NEV
UTAH
ARIZ
699
99%
WYO
COLO
1110
78%
N MEX
306
97%
N DAK
S DAK
NEBR
1650
48%
KANS
803
60%
OKLA
338
81%
TEX
1858
94%
MINN
10%
IOWA
8%
MO
10%
ARK
LA
WIS
ILL
7%
MICH
IND
OHIO
KY
TENN
MISS
ALA
GA
FLA
S C
N C
VA
W VA
MD
DEL
D C
PA
N Y
N J
CT
R I
MASS
VT
N H
MAINE

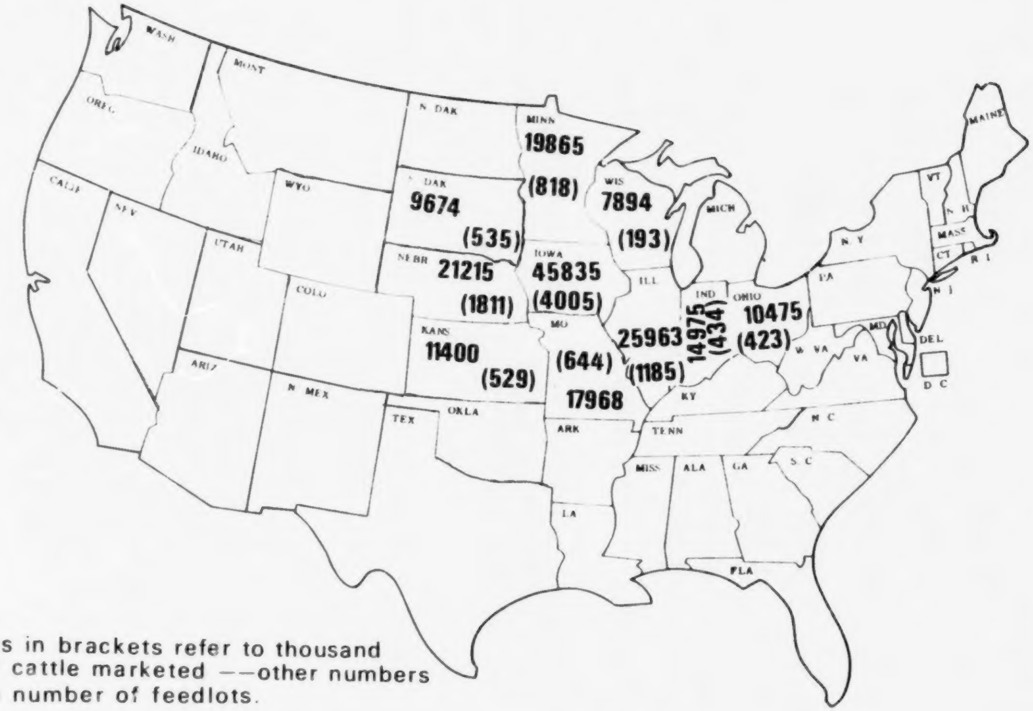
▨ Indicates the ten States West and South of the Missouri River which account for almost 90 percent of all cattle marketed from lots with capacities of 1,000 head and greater.

Top number shown in each State refers to thousand head of cattle marketed from lots with capacities of 1,000 head and greater.

Percentages shown refer to the percent of cattle marketed from feedlots with capacities of 1,000 head and greater.

Map 4

Number of Feedlots of under 1,000 Head Capacity and Number of Cattle Marketed From Them for Ten Selected Midwestern States, 1968.


WASH
MONT
N DAK
MINN
19865
(818)
OREG
IDAHO
WYO
S DAK
9674
(535)
WIS
7894
(193)
MICH
N Y
VT
N H
MASS
CT
R I
MAINE
CALIF
NEV
UTAH
NEBR
21215
(1811)
IOWA
45835
(4005)
ILL
25963
(1185)
IND
14975
(434)
OHIO
10475
(423)
PA
N J
MD
DEL
D C
COLO
KANS
11400
(529)
MO
(644)
17968
W VA
VA
KY
ARIZ
N MEX
TEX
OKLA
ARK
TENN
N C
S C
MISS
ALA
GA
LA
FLA

Numbers in brackets refer to thousand head of cattle marketed —other numbers refer to number of feedlots.

Totals for the ten States shown on map:
Cattle marketed--10,557,000 head
Feedlots--185,264

Average number of cattle per feedlot--57 head

Table 4. Number of feedlots in selected States with under 1,000 head capacity, number of cattle marketed from them, and their average marketings--1968.

Name of State	Number of lots under 1,000 head	Number of cattle marketed from lots under 1,000 head	Average marketings
Iowa	45,835	4,005,000	87
Illinois	25,963	1,185,000	46
Nebraska	21,215	1,811,000	85
Minnesota	19,865	818,000	41
Missouri	17,968	644,000	36
Total	130,846	8,463,000	65

Source: Cattle on Feed, January 1, 1969, Statistical Reporting Service and Crop Reporting Board, United States Department of Agriculture, Washington, D.C.

Table 5.--Number of feedlots in selected States with 1,000 head capacity and over, number of cattle marketed from them, and their average marketings--1968.

Name of State	Number of lots of 1,000 head and over	Number of cattle marketed from lots of 1,000 head and up	Average marketings
California	288	2,041,000	7,087
Texas	294	1,858,000	6,320
Nebraska	463	1,650,000	3,564
Colorado	97	1,110,000	11,443
Kansas	100	803,000	8,030
Arizona	68	699,000	10,279
Iowa	165	345,000	2,090
Oklahoma	54	338,000	6,259
Idaho	81	338,000	4,173
New Mexico	40	306,000	7,650
Total and Average	1,650	9,488,000	5,750

Source: Cattle on Feed, January 1, 1969, Statistical Reporting Service and Crop Reporting Board, United States Department of Agriculture, Washington, D.C.

There does not appear to be any close relationship between the number of lots involved and the average size of marketings from these over 1,000 head capacity lots. Colorado, for example, had 97 lots making up the high end of the range of averages while Iowa had 165 lots making up the low end of the averages. Out of this ten State group California, Texas, and Nebraska had the largest number of lots over 1,000 head while New Mexico, Oklahoma, and Arizona had the fewest.

The distribution by size of feedlots within the 1,000 head and greater capacity lots provides an indication of the control problems by lot size and regional location. In general, as lot sizes increase there is a progressively greater wastes handling problem. With increasing lot sizes there are increasing quantities of wastes to be handled, more wastes to be stored prior to disposal, and the ratio of nearby land available for waste disposal to the quantity of wastes decreases. This means that day-to-day wastes handling problems of large lots are similar to those of small lots and yet different enough to require different solutions. Use of nearby land, for example, can minimize storage requirements, reduce quantities of wastes subject to runoff, and provide for disposal of runoff caught in detention ponds. However, use of nearby land for disposal from very large feeding operations can create additional potential water pollution situations because of the size of the disposal problem.

Increasing quantities of wastes to be disposed can mean increasing travel distances to the last added disposal site, increasing quantities of wastes per disposal site, or some combination of both. From a disposal cost standpoint the least-cost method is to add greater quantities of wastes to the nearby sites, at least up to some point prior to decreasing crop returns. However, increased quantities of wastes disposed per unit of land increase the likelihood of water pollution from the disposal areas and may even increase the total water pollution problem rather than decrease it.

As would be expected, the number of feedlots in each size category declines very rapidly as the lot capacities increase beyond 1,000 head. (See Table 6.) However, the trends do indicate that all feedlot sizes will be increasing and that there will be continued growth in the number of large-scale lots. The 32-State total in Table 6 shows that the bulk of the 1,000 head capacity lots fall within the 1,000 to 3,999 head capacity range. In fact, if the range is expanded to include up to 7,999 head capacity lots, this new range includes 1,805 of the 2,080 lots with capacities of 1,000 head and greater.

Table 6.--Number of cattle feedlots in various specified size groups in selected States--1968.

Name of State 1/	Feedlot capacity size ranges				
	1,000 to 1,999	2,000 to 3,999	4,000 to 7,999	8,000 to 15,000	16,000 and up
	Number of feedlots in each range				
California	75	85	55	45	28
Texas	121	68	52	30	23 2/
Colorado	21	30	20	16	10 2/
Kansas	24	28	23	17	8
Nebraska	270	113	57	15	8 2/
Arizona	13	15	21	10	9 2/
New Mexico	8	14	6	8	4
Oklahoma	24	17	4	6	3
Idaho	35	19	19	5	3
Iowa	113	35	13	4	0
Ten-State tot.	704	424	270	156	96
32-State total	967	522	316	176	99

Source: Cattle on Feed, January 1, 1969, Statistical Reporting Service and Crop Reporting Board, United States Department of Agriculture, Washington, D.C.

1/ The numbers shown by States under any specified size group may have been conbined in the source table to avoid identifying individual operations.

2/ Lots from larger size groups have been included in this group in the source table to avoid disclosing individual operations.

From the foregoing discussion it is evident that there are some definite points to be considered when assessing the need for and applicability of pollution control measures for various sized feedlots. Additional breakdowns of the large-scale feedlot figures in Table 6 show that 96 out of a total of 99 feedlots with capacities of 16,000 head and over are accounted for by nine of the ten top States in cattle marketings from lots over 1,000 head capacity. Also, it shows that these ten States account for 252 of the 275 lots with capacities of 8,000 head and greater.

A comparison of Tables 6 and 7 provides an indication of the trend toward larger feedlots. In 1962, there were only 1,517 lots with capacities of over 999 head compared to 2,080 such lots in 1968. The absolute increase declined by size range as the size ranges increased. That is, increases in feedlot numbers from 1962 to 1968 ranged downward from 166 additional lots in the 1,000 to 1,999 head capacity group to 68 lots in the 16,000 head and over group. However, the percentage changes in feedlot numbers followed an exactly opposite trend. In relative terms, therefore, the larger lots showed larger increases from 1962 to 1968. That is, the increases ranged upward from 21 percent for the 1,000 to 1,999 head capacity group to 219 percent for the 16,000 head and up group.

From Map 3 and Table 6 it can be seen that most of the large feedlots are located south and west of the Missouri River. Although specific feedlot locations and corresponding climatological data are not presently available, it is known that the climate is less severe in most of these States than in the States where the majority of the small lots are located. In fact, in several of the States with the majority of the large lots, the climate can be considered as dry.

Another perplexing problem, in terms of evaluating the current pollution problem and forecasting future changes, is how to differentiate size groups in the 206,516 lots of under 1,000 head capacity. In this size group the average number of cattle marketed in 1968 was 59 head. Even if the lots are restricted to those found in the ten midwestern States with somewhat similar climatic conditions, the magnitude of the problem remains large. That is, in these ten midwestern States there were 185,264 lots of under 1,000 head capacity. About 10.6 million head of cattle were marketed out of these lots in 1968 for an average marketing of 57 head. (See Map 4 .)

Feedlot operations are not continuous year-around operations for the vast majority of feeding enterprises. That is, the lots are not used for cattle feeding during some substantial portion of the year. Although there is a great deal of variation among feeding enterprises in the length of time cattle are kept on feed and in the number of feeding cycles completed annually, a common feeding program handles only one feeding cycle annually and the cycle usually lasts from 90 to 120 days.

Table 7.--Number of cattle feedlots in various specified size groups in selected States--1962.

Name of State 1/	Feedlot capacity size ranges				
	1,000 to 1,999	2,000 to 3,999	4,000 to 7,999	8,000 to 15,000	16,000 and up
	Number of feedlots in each range				
California	106	100	41	37	16
Texas	98	60	31	14 2/	0
Colorado	31	19	16	14 2/	0
Kansas	24	8	12	9 2/	0
Nebraska	202	75	24	11 2/	0
Arizona	30	25	21	11	7
New Mexico	10	12	7	5	0
Oklahoma	13	10	6 2/	0	0
Idaho	37	12	11 2/	0	0
Iowa	33	3 2/	0	0	0
Ten State Total	584	324	169	101	23
32-State Total	801	385	194	106	31

Source: Cattle on Feed, January 1, 1969, Statistical Reporting Service and Crop Reporting Board, United States Department of Agriculture, Washington, D.C.

1/ The numbers shown by States under any specified size group may have been combined in the source table to avoid disclosing individual operations.

2/ Lots from larger size groups have been included in this group in the source table to avoid disclosing individual operations.

In the Midwest, cattle feeding operations are generally only one portion of the overall farm enterprise. By feeding cattle during the late fall through early spring period, feeding operations can take advantage of off-season labor availability and home produced feeds. On the other hand, as feeding enterprises increase in size, with the resultant larger capital investments in fixed facilities and the necessity for additional labor, the feeding operations tend to become year-around with a constant turnover of animals through the lots.

Since feeding operations are intermittent, the number of lots in operation at any single point in time is less than the total number of lots operating during some part of the year. Table 8 shows the estimated numbers of feedlots and cattle and calves on feed on April 1, 1966 by various size categories.

The estimated feedlot and cattle numbers in Table 8 are the most recent estimates available on such a broad geographical base. Although since then changes have undoubtedly occurred in total numbers as well as in numbers within size groups, any changes that occurred in such broad ranges and on a national scale would not effect the points made here.

Most of the feedlots in operation on April 1, 1966 (Table 8) had capacities of less than 151 head and accounted for over one-third of the total cattle on feed at that time. Thus, it can readily be seen that any determination of feedlot pollution problems and costs of pollution control must ultimately either include or exclude these relatively small lots from specific consideration. If these lots can generally be excluded because they are not a source of water pollution, the total cost estimates of pollution control will be reduced. Conversely, if these lots are shown to be sources of water pollution, applicable control measures must be developed and their costs included in the total cost estimates.

The concept of feedlot location by climatic region discussed previously showed how the feedlots marketing cattle in 1968 were distributed by State. In general, this discussion concluded that the smaller lots were located in the States with colder and more humid climates while the very large lots tended to be found in the States with warmer and less humid climates.

If the geographical regions shown in Map 5 are used as a base for describing feedlot locations on April 1, 1966, the sharp demarcation of average lot sizes among regions can be seen (Table 9). Of course, there is some masking effect, because of the use of averages, on the growing number of large-scale feedlots in each area, especially in the Northern Plains region. In fact, the earlier discussion pointed out that Kansas and Nebraska actually fell into a dual category being major locations of both large and small feedlots.

Table 8.--Total operating feedlots and total cattle and calves on feed by specified feedlot size groups, April 1, 1966.

Feedlot size group	Feedlots with cattle and calves on feed	Total cattle and calves on feed	Average per Feedlot
	Number	Head	Head
1 to 50	73,704	1,692,000	23
51 to 150	23,131	2,146,000	93
151 to 300	8,930	1,919,000	215
301 to 500	1,927	770,000	400
501 to 1,000	1,032	709,000	687
1,001 to 5,000	548	1,149,000	2,097
5,001 and up	166	1,842,000	11,096
32-State total	109,438	10,227,000	93

Source: Urea Consumed by Cattle on Feed, Feeding Year 1965-66, Agricultural Economic Report No. 158, Economic Research Service, United States Department of Agriculture, Washington, D.C.

Map 5

Description of Geographic Regions.

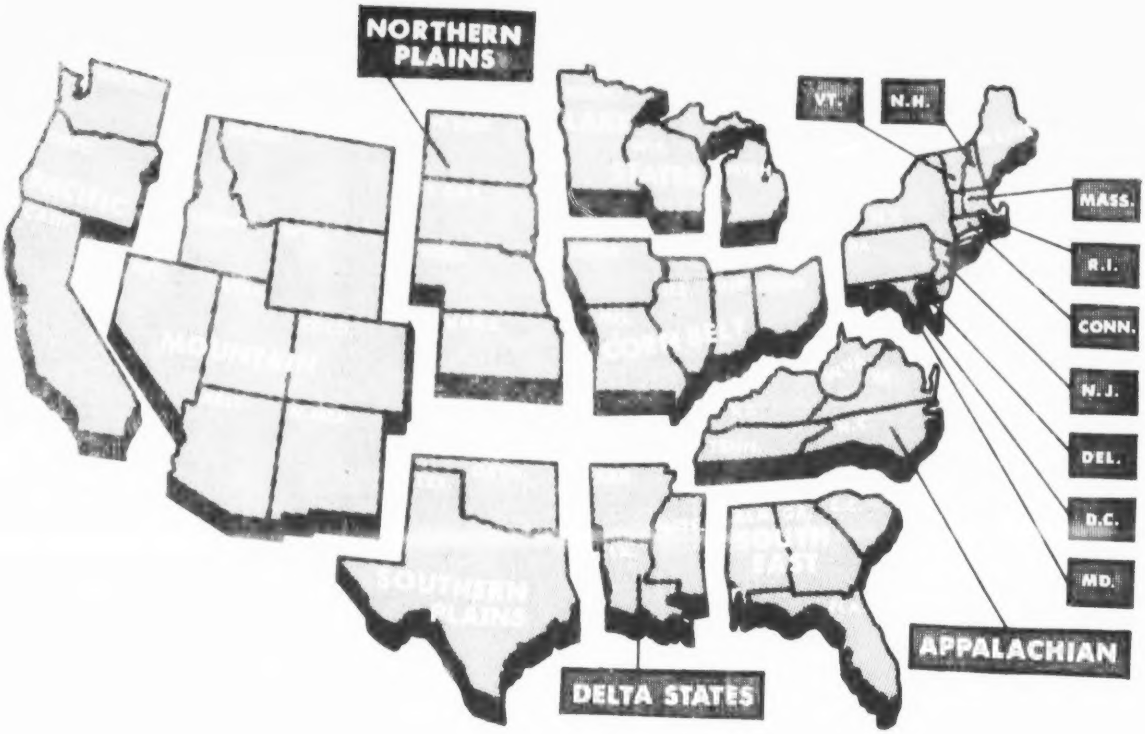

NORTHERN PLAINS
VT.
N.H.
MASS.
R.I.
CONN.
N.J.
DEL.
D.C.
MD.
PACIFIC
MOUNTAIN
LAKE STATES
CORN BELT
SOUTHERN PLAINS
DELTA STATES
SOUTHEAST
APPALACHIAN

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Table 9.--Total operating feedlots and total cattle and calves on feed by specified region, April 1, 1966.

Production Region	Feedlots with cattle and calves on feed	Total cattle and calves on feed	Average per Feedlot
	Number	Head	Head
Northeast	2,005	77,000	38
Lake States	18,154	815,000	45
Corn Belt	59,196	3,918,000	66
Northern Plains	24,086	2,114,000	88
Appalachian	669	91,000	136
Southeast	623	142,000	228
Delta States	160	12,000	75
Southern Plains	1,082	662,000	612
Mountain	2,613	1,359,000	520
Pacific	850	1,037,000	1,220
32-State total	109,438	10,227,000	93

Source: Urea Consumed by Cattle on Feed, Feeding Year 1965-66, Agricultural Economic Report No. 153, Economic Research Service, United States Department of Agriculture, Washington, D.C.

Common Control Methods

Beef feedlots are known sources of water pollution but the extent and distribution of pollution caused by such feedlots is unknown. Further, the present state of knowledge does not permit an adequate estimation of the numbers or types of control facilities that are needed to control water pollution from feedlots. However, an indication of the size and variability of the control problem may be obtained through a general discussion of the known control methods and their applicability under varying conditions.

Types of pollution control measures utilized by feedlot enterprises will vary significantly across the nation as well as within a specific local area. There is no one best solution for controlling pollution from feedlots although there are solutions that have general applicability to feedlots in similar situations. In fact, it is this general applicability in similar situations which will allow future estimations to be made as to the total costs of controlling pollution from animal feedlots.

Control measures range widely in complexity and cost. Minimal control measures, in terms of cost and complexity, are water diversion systems that divert drainage water around the feedlots, changes in the drainage route of runoff from feedlots, and, possibly, changes in lot locations to minimize drainage water moving across the lot or to prevent direct drainage from the lot to a watercourse. Other changes in operations such as increasing animal concentrations through decreasing lot sizes or adjusting feeding cycles to meet changing climatic conditions can, in some cases, also be used to reduce or eliminate water pollution from feedlots with minimum expenditures.

More costly control measures, at least in terms of capital investments and operating costs, would include systems with completely covered feeding operations and full treatment of the wastes. Of course, between the minimal control situation and the maximum control situation there are numerous other control measures and combinations of these measures that can be used.

For the vast majority of feedlots the determination or estimation of total wastes washing from the lot is probably irrelevant. The critical factor that must be determined is whether or not runoff from the lot ever results in water pollution. If the lot is a source of water pollution, whether regular, intermittent, or seldom, it is reasonable to assume that the pollution must ultimately be controlled.

The type of control measure adopted by any lot contributing to water pollution does not depend upon the amount of wastes washed from the lot. Rather, the control measure adopted depends upon a variety of factors chief among which are the amounts of water that must be contained or diverted, the possibility of cost savings, and the ability of the system to offset inadequate labor supplies. Intertwined with these chief factors in determining the type of control measure to be adopted are such things as lot size, climate, and type of feeding operation.

For purposes of describing some common control measures and their applicability to similar feedlot situations, feedlots may be categorized as small, medium, large, and extra large. Realizing that there is no single point, or even series of points, at which feedlot sizes can be divided to provide all-inclusive descriptive feedlot categories, the following numerical definitions may be used to describe small, medium, large, and extra large feedlot categories. Small lots range from zero through 150 head capacities, medium lots from 151 through 1,000 head capacities, large lots from 1,001 to 15,999 head capacities, and extra large lots range upward from 16,000 head.

Small lots are found across the country but are most prevalent in the midwestern region. If these lots are sources of water pollution, the easiest and most likely control measure to be implemented is a combination of water diversion around the lot and changes in lot size to obtain proper animal concentrations for runoff minimization. In some cases relocation of the lot may be needed to accomplish the necessary control but there is usually strong resistance, for a variety of reasons, to lot relocation.

Lagooning or detention of the wastes as well as covering of the feeding operations can be used to provide the needed pollution control although it is doubtful that such measures will find extensive use in small operations. Climate has little effect on the type of control measure applicable to small lots since the same measures are both effective and least-cost in humid as well as dry areas. However, there is less likelihood of water pollution occurring from a small lot located in a dry area.

Medium and small sized lots often have similar water pollution problems and solutions. Therefore, medium sized lots cannot always be categorically separated from small lots. However, there are large numbers of lots in the medium category that require more extensive control measures than the small lots require.

Medium lots in dry areas may be able to control pollution through use of water diversion methods and sizing of lots to optimize animal concentrations or, in some cases, through a combination of both methods along with a detention pond. Humid areas and areas with cold climates may make use of various combinations of control methods such as water diversion and detention, covered feeding operations, lots sized to optimum animal concentrations, and lagooning of the wastes. Although water recycling is generally considered as being best suited to dairy, hog, or poultry operations with water flushing systems, it is possible that further refinement or research may prove the system feasible for medium to large feedlots.

Large lots, which fall between the medium and extra large categories, need not be specifically discussed. The control measures utilized by this group will closely parallel those utilized by the adjoining groups, depending upon such items as climate, management requirements, present facilities, and lot location.

Extra large lots are generally found in the drier and milder climates. Therefore, solutions such as water diversion, lot sizing for optimum animal concentration, and supplementary detention ponds are likely to be used in extra large lot situations. In some cases complete elimination of runoff results when slotted floors and pit storage of the wastes under the animals are used as part of the wastes handling and nuisance control program.

In cases where extra large feedlots are located in harsh or humid climates, covered feeding operations with slotted floors and pit storage of wastes under the animals is a possible means of controlling water pollution. Such a system is, of course, a positive method of runoff control but the investment costs in buildings, floors, and pits are quite high. Therefore, the attractiveness of such a system to feedlot operators lies mainly in the cost reductions that accompany installation of the system. Savings resulting from installation of the system might come from items such as decreased land, plumbing, surfacing, and fencing requirements, lower disease and death loss rates, higher degrees of nuisance control, lower labor requirements, decreased equipment maintenance costs, and ease of management control.

The preceding discussion of feedlots by size categories generally touches upon common water pollution control measures that might be employed by lots in similar circumstances in the various size categories. This discussion is not meant to be completely comprehensive nor is it meant to imply that these measures are acceptable in all cases. Rather, the discussion is presented to show that there are common factors which can be utilized in developing estimates of the cost of controlling water pollution from feedlot operations.

Other systems which incorporate almost complete elimination of wastes may find extensive use in the future because of their labor saving qualities. For example, incineration of wastes on a daily basis or some form of treatment process that reduces or minimizes waste handling might be practical under certain conditions. Although the costs, including loss of value of the wastes as fertilizers, feeds, soil conditioners, etc., make the wastes elimination systems unfeasible under present conditions, such systems should be considered over time in the event that changes in cost relationships or in feedlot operations make the systems feasible for adoption by the industry on a broad scale.

Description of Selected Control Methods

This section briefly describes some of the control methods presently in use by the cattle feeding industry that appear to have potential for widespread adoption as discussed in the previous section. These control methods, depending upon the particular circumstance, may be used alone or in combination with one another. Water diversion, for example, may be used in conjunction with most of the other methods to enhance their effectiveness or decrease their costs.

It is concluded that although these methods have potential for widespread adoption, additional study and analysis is required before they can be used as a basis for estimating total feedlot pollution control costs. The costs and savings resulting from adoption of each control method should be determined along with the applicability of each type of control measure to various feedlot situations. Also, the growth of the feeding industry needs to be predicted by location, lot size, and animal numbers. This growth prediction should take into account development of new technology and the effects of overall environmental pollution control requirements on the industry. Water or air pollution abatement costs, for example, could change the comparative advantage relationships among regions that now exist.

Covered feeding operations can provide a means of water pollution abatement for all sizes of feedlots in harsh and humid climates. However, they may find their most extensive use in the medium to large size categories when pit storage of the wastes with a liquid wastes handling system have been incorporated in the building setup.

Partially covered feeding operations are found in many small feeding enterprises because barns and other buildings are available for conversion to shelter uses. Partially covered lots can contribute to water pollution control but the effect is highly variable, depending upon the extent of covering and season of the year. Very limited cover relative to feedlot size and number of animals does not provide much runoff control during most seasons. However, during very cold weather the shelter may be used extensively by the animals which keeps the wastes generally confined to the covered area. However, disposal of the wastes may create a water pollution hazard unless proper safeguards are followed. In cold climates, over-winter storage of the wastes in controlled runoff areas may be required. In all climates adequate storage areas for wastes accumulated during wet periods may be necessary. In any case, the costs of these additional safeguards must be considered along with the shelter costs when estimating total costs.

Fully covered operations are most practical when slotted floors and pit storage for the wastes are provided. Although addition of these two items significantly raises the capital costs, they do allow the system to take full advantage of labor savings, wastes quality control, and savings in land, fencing, buildings, lot surfacing, and associated costs. There are, however, some additional problems associated with a liquid wastes handling system that must be considered in analyzing the feasibility of a covered feeding operation with a liquid wastes handling system.

Diversion

Routing water away from feedlot surface or away from a watercourse, where applicable, is probably the easiest and least-cost method of controlling water pollution from feedlots. In its simplest form diversion can be accomplished by diking or channelling on the high end of the feedlot and along the sides so that water from other surface areas is channelled around the lot. Such diking or channelling can generally be accomplished with operator labor and equipment. However, the operator may require outside consultation to determine the necessary size for the dikes or channels to accommodate climatic and hydrological aspects of the area. He will also need to provide the proper slope and use adequate materials to prevent erosion or gullying when the dikes or channels are installed.

The optimum concentration of animals in the lot can be used alone or in combination with other measures to prevent water pollution from runoff or to minimize costs of other pollution control measures. When used in conjunction with diversion measures, for example, optimum animal concentrations can reduce the needed footage of diversion channels or dikes; that is, optimum animal concentrations can mean that the same number of animals are fed in a smaller land area. Therefore, the three sides requiring diversion measures are smaller for the same number of animals.

Changes in lot location can also be a method of water pollution control or a cost minimization technique when used in combination with other control measures. Locating the lot well away from watercourses or drainage channels can prevent water pollution stemming from the feedlot surface. In other cases the lot may be relocated to minimize the encroachment of surface water from other land areas around the feedlot. Reduction in outside runoff water reduces the need for, or size of, other control measures such as diversion structures, or detention ponds and lagoons. The cost of lot relocation depends upon several factors such as other uses that can be made of the present lot, its facilities, convenience of the new location for labor and herd management, fencing, surfacing, building, and associated costs necessary to make the new location usable.

Detention

Runoff water detention is another method for complete control of water pollution from the feedlot if the detention ponds are sized properly to handle maximum rainfalls and accumulations during extended rainfall periods when the ponds cannot be emptied. The following description of a feedlot utilizing a runoff detention system explains how the system operates and details some of the system's limitations.

In broad terms a runoff detention system must incorporate water channelization measures in the feedlot layout, have an adequate holding pond or area, and have an acceptable method of removing some or all of the runoff from the detention pond between rainfalls. It can also be assumed that, where feasible, runoff minimization techniques such as proper lot location, optimum animal concentrations, and water diversion measures will be adopted in conjunction with the detention system. Such techniques decrease the necessary detention pond size and lower the volume of runoff to be disposed of, both of which reduce the costs of a detention system.

Channelization requirements are basically the same irrespective of the type of detention pond evacuation system employed. In order to effectively use a detention system the feedlot must be sloped or drained so as to channel all the runoff water into the detention pond. In addition, the shaping should probably minimize the amount of solids transported from the lot into the detention pond.

The size or capacity of the detention pond is dependent upon the climate, lot size, and type of evacuation system employed. For purposes of illustration here the evacuation systems are limited to either an evaporation system or a mechanical system using a pumping operation combined with irrigation disposal.

Evaporation systems, because of the water surface area required for evaporation, are only practical in areas where the evaporation rate is relatively high compared to the precipitation rate. Also, such a system presupposes that odors associated with the pond will be within an acceptable range.

The primary advantages of an evaporation system are minimal operation costs and limited management requirements. If the evaporation pond has been adequately designed, natural evaporative processes remove the runoff water from the pond. Therefore, there is no operating cost nor any need for management of the runoff removal associated with an evaporation system as opposed to a mechanical pump-out system. However, there is the cost of periodic cleaning of the evaporation pond which may or may not be required as frequently as cleaning of ponds using mechanical evacuation. Also, there is a management factor involved in the cleanout. That is, the evaporation ponds must be cleaned before the accumulating solids transported into the pond by runoff water build up to a point where the remaining pond capacity is inadequate to detain all the runoff.

Major disadvantages of an evaporation system, even in a suitable climate, are the land requirements and complete dependence upon natural processes to remove collected runoff water. Land requirements for the evaporation pond are directly related to runoff volume and inversely related to the evaporation rate. That is, the surface area of the water that must be exposed to the air for evaporative purposes decreases as the rate of evaporation increases but as total runoff increases the pond size must increase.

For any given area, once the evaporation rate has been determined, the ratio of required surface area to runoff volume will probably remain constant. Therefore, for each increase in runoff volume a proportionate increase in surface area is necessary. In contrast, a mechanical system can accommodate larger runoff volumes by increasing pond capacities through increases in pond depths rather than in surface area. Also, in contrast to the mechanical system, the evaporation pond must be substantially larger to allow for the slower rate of runoff water removal. Additionally, because of the large surface area required and the total amount of runoff that must be retained, the evaporative system adds to its own size requirements by providing a larger surface area for rainfall collection.

Complete dependence upon natural processes must either more than proportionately add to the design size of the system when compared to a mechanical evacuation method or decrease the reliability of the evaporation method. In other words, an additional variable, i.e., evaporation rate, must be taken into account when designing the evaporative system. Changes in the evaporation rate because of such factors as cloud cover or humidity changes do not affect the mechanical system but are important to the evaporative system.

Modified versions of the detention pond may also be used where evaporative systems are feasible. One modified version would involve ridging and furrowing the lot surface to detain the runoff on the lot proper rather than in a special pond. Such a method would be subject to the same climatic limitations as the evaporation pond but there is a possibility of land savings with on-the-lot detention and evaporation. However, there is no information presently available as to the additional land requirements, if any, to provide adequate space for the cattle and at the same time allow space for detention and evaporation of occasional rainfalls.

Mechanical evacuation is accomplished by means of a pump removing water from the detention pond and forcing it through piping to a disposal area. The disposal area may be one of three general types: productive land, non-productive land, or land removed from production.

The runoff water and wastes may be pumped from the pond and sprayed onto productive crop or pasture areas in concentrations and quantities that add to the fertility of the soil but do not exceed the crop's requirements, impair crop growth, or adversely affect soil structure. Using a crop or pasture disposal area provides a fertilizer value offset to the waste disposal costs, does not remove land from remunerative production, and makes use of land that may be more readily available than non-productive land sites. Chief disadvantage of such a disposal area is the large land requirement which results in greater costs for piping and pumping, especially as the feedlot sizes become very large. Also, the pond evacuation must often be undertaken during wet periods when soil moisture is already high. However, with a large enough disposal area, this wet weather evacuation could most likely be accomplished without detrimental effects to either crops or water quality.

Non-productive land can be used as an evaporation area for the disposal of runoff water from the detention ponds. Owens and Griffen 2/ considered the use of playa lakes in the Texas High Plains area as possible disposal sites for runoff water pumped from detention ponds. It was concluded that use of a playa lake was a low cost disposal method since no land had to be taken out of production to provide the disposal site. Other non-productive land could similarly be used but it would also have to meet certain requirements. First, there should be no problem with surface runoff from the disposal area. Second, the soils and groundwaters should be studied to assure that no pollution occurs through percolation of the wastes through the soil into groundwater. Third, odors, nuisances, and similar problems associated with the disposal site should be within acceptable limits. Fourth, if the water at the disposal site is to be used for other purposes such as irrigation or livestock watering, the nutrient, mineral, and salt concentrations must be carefully monitored to prevent any undesirable side effects from the presence of the runoff water.

2/ Economics of Water Pollution Control for Cattle Feedlot Operations, Owens, T.R. and Griffen, Wade L., September 1968; Department of Agricultural Economics, Texas Technological College, Lubbock, Texas.

It is possible that land could be removed from production and used primarily as a disposal site for runoff pumped from the detention pond. Under such a system the disposal site might be used for growing some type of salt-tolerant crop but the crop itself would have to be of secondary importance. Studies reported by Wells et. al. [3], for example, indicate that high rates of runoff water application are detrimental to several types of crops but that Midland Bermuda grass has a high tolerance for such runoff.

Primary disadvantages of this land removal system are the high cost of the land removed from production and the lack of information regarding movements of nutrients, salts, and minerals through various soil types under heavy runoff application rates. Additional questions also remain as to the long-term effect of the high disposal rates on soil structure. If the soils eventually puddle and lose their absorption capacity, then the disposal area will become an evaporation area subject to the same restrictions as cited previously for non-productive land.

The size of detention pond necessary with a mechanical evacuation system depends upon the size of the feedlot, maximum and cumulative rainfalls, and the size of the evacuation system. Unlike the evaporation system, the land requirements for a pond with a mechanical system can be minimized by increasing the pond's depth. Of course, there are practical limits to pond depth and they will vary from area to area. Design analysis of individual feedlot enterprises of regional variations can be used to determine the least-cost combination of pond size, depth, and pumping capacity. In some cases land costs or availability may be such that extra costs for increasing pond depths are justified. On the other hand, ample or cheap land may justify the use of larger and shallower ponds with consequent lower pumping capacity needs and decreased pond construction costs.

Even in cases where runoff detention is feasible, it only provides a solution to one part of the enterprise's wastes management problem. Each animal daily deposits the equivalent of about ten pounds of dry waste material on the feedlot surface. Although some of the wastes may be washed from the lot into a detention pond by rainfalls, the major portion of the wastes must be mechanically removed from the lot at varying time intervals. These wastes may be immediately disposed of in conjunction with the cleaning process but, for the larger lots, the wastes are most likely stacked to await disposal at a more opportune time. Safeguards must, therefore, be instituted to assure that runoff from the stacks is contained or channelled into a detention pond and that field disposal does not subsequently result in water pollution.

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[3] "Characteristics of Wastes from High Plains Cattle Feedlots," Wells, Dan M., Grub, Walter, Albin, R.C., Meenaghan, George F., and Coleman, Eugene, Paper presented at ASCE, Fall Meeting, Texas Section, Lubbock, Texas, October 1969.

Covered Operations

Covered feeding operations with pit collection and storage of the wastes under the animals, although still relatively rare operations, are apparently gaining in popularity in the colder climates. Use of such covered feeding systems can be one solution to water pollution problems from fat cattle wastes if care is taken when the wastes are disposed of on land areas.

A typical fully covered feeding operation with under-animal storage is designed so as to keep all of the animals under cover at all times during the feeding cycle. In order to accomplish this with current technology, the simplest method is to provide a three-sided pole barn with metal sides and roof, a cement pit under the roof, and a slatted floor covering over the pit. Although one full lengthwise side of the building remains open to provide adequate ventilation in both winter and summer, almost all precipitation is kept away from the animals and their wastes.

Slatted floors are used in conjunction with pit storage to allow the wastes to fall into the pit and thereby avoid any wastes build-up between cleanings. The size and spacing of slats may vary but a common size is five inches in width with spacings of one and one-half inches between the slats. In some cases the slat is slightly raised in the center to facilitate automatic cleaning. Action of the cattle's hooves and their body heat tends to prevent a manure build-up on the slats in all but the coldest weather if proper animal concentrations are maintained.

Since wastes are automatically moved downward through the slatted floors, pits must be provided for accumulation of the wastes. The size of pit is dependent upon the frequency of cleaning but in cold climates it appears desirable to have adequate storage for at least three months and probably longer. Added storage allows more flexibility in the cleaning operations and is particularly important when weather conditions do not permit spreading of the wastes.

Wastes accumulated in the pit are in a slurry form and can be handled as a liquid. As a rule, when cleaning operations are begun, a rotary pump is placed in the pit in the reverse operating position so that the wastes are circulated and thoroughly mixed. The pump is then operated in the forward position and the wastes pumped into a specially built tankwagon for removal to the disposal area.

Although it is possible for any size feeding enterprise to utilize a liquid wastes handling system, costs of pumping and hauling equipment reduce the economic feasibility of such systems for smaller enterprises. Pits, floors, and buildings can be scaled to any desired capacity but pumping and hauling equipment cannot be purchased in sizes smaller than the manufacturer's minimum size. Therefore, the fixed cost of the oversized equipment is spread over only a few animal units in the smaller enterprises which results in a high average unit cost for the system.

Even for enterprises sized to take advantage of economies of size associated with wastes handling equipment and facility construction, the costs of providing full cover and a liquid wastes handling system are significantly greater than costs of a standard open lot. Therefore, the covered system must have offsetting operating advantages or economies to make it practical for adoption. Wastes accumulated in pit storage, for example, maintain their fertilizer value and can be readily analyzed for nutrient content. Analyses have shown that a ton of beef cattle wastes contain about 6.5 pounds of nitrogen, 4.5 pounds of phosphate and seven pounds of potash. Also, there is no bedding cost with a covered system and labor costs are reduced while herd care and management is enhanced.

Another prime savings attributable to a covered system is in land needs. With a covered system each animal requires slightly more than 20 square feet of lot or floor space. When compared to the 100 to 150 square feet needed on hard surfaced open lots and the over 200 square feet required for dirt surfaced lots, it is evident that land and associated confinement costs such as fencing are substantially lower for the covered system. There is also evidence indicating that feeding efficiency is improved during the winter when animals are provided with simple shelter similar to that of a covered feeding system. Disease problems and death losses can also be reduced with the covered system because of lowered stress on the animals and increased herd management. A final saving on men and equipment is possible when part of the covering is over driveways and feeding lines so that equipment can be moved freely during the most adverse weather conditions.

More detailed studies in the future will determine the actual costs and savings attributable to the aforementioned factors that are part of a covered feeding system. Once the costs and savings have been determined by enterprise size and location, the applicability of this system as a water pollution control measure can be predicted and used in estimating total water pollution control costs. The interaction of all pollution control requirements (e.g., air and water pollution and nuisance control regulations) and changes in feeding technology and equipment must be factored into the prediction of regional cattle feeding locations. These factors can change the costs of feedlot operations and are particularly important in analyzing the future of covered feeding systems. Added costs in the mild climates may reduce or eliminate the comparative advantage now found in these milder climates.

Such a change in comparative advantage could result in future shifts in the production locations in favor of the harsher and more humid climates. Shifts in production areas would, in turn, bear on the estimated costs of animal wastes pollution abatement.

The selected control methods summarized here are just a few of the many control measures that might be used in animal wastes pollution abatement. Although these measures appear to be relatively low in net cost and widely applicable, there are other more costly measures that may be required in special circumstances. The general control measures discussed do, however, serve to indicate avenues of analysis and courses of future study for use in developing estimates of the total cost of controlling water pollution from feedlots.

DAIRY CATTLE

The number of milk cows on farms has steadily declined over the past couple of decades (See Table 10). This decline extends from a peak of 25.6 million head in 1944 to 12.7 million head in June 1969. Despite this decline, however, the number of cows remaining, combined with the changed technology, i.e., greater use of cleaning water, more intensive confinement, increased production per animal, and more animals per enterprise, make further investigation into the water pollution potential of dairy farms necessary.

TABLE 10

Number of Milk Cows on Farms, 1944-1969 1/

Million Head

1944---25.6
1945---25.0
1946---24.1
1947---23.3
1948---22.3
1949---22.0
1950---21.9
1951---21.5
1952---21.3

1953---21.7
1954---21.6
1955---21.0
1956---20.5
1957---19.8
1958---18.7
1959---17.9
1960---17.6
1961---17.4

1962---17.1
1963---16.5
1964---16.1
1965---15.0
1966---14.1
1967---13.5
1968---13.0
1969---12.7

1/ 1944-1964: Average number on farms during year, excluding heifers not yet fresh.
1965-1969: Number on farms on June 1 of each year.

Sources: "Statistical Bulletin No. 303" and Supplements, Economic Research Service, United States Department of Agriculture, Washington, D. C.

Milk Production, August 12, 1969, Statistical Reporting Service and Crop Reporting Board, United States Department of Agriculture, Washington, D. C.

Dairy farm operations may fall into any one of the four discharger categories used in this report. However, trends toward larger herds and increased need for labor efficiency tend to shift the operations within the discharger categories so that a greater proportion of the operations fall into the higher discharge frequency categories. For example, hydraulic flushing reduces labor requirements for the cleaning operations but almost invariably the operation then discharges wastes regularly. The same type of shift occurs when small operations with little or no water pollution potential go out of business but their animals are purchased by other dairy enterprises that have a greater water pollution potential. Thus, the trend to fewer and larger dairy farms does not necessarily mean that water pollution will decrease. However, it does mean that the enterprises will be easier to locate and aid in pollution control since they will be fewer and have more common problems and solutions.

Location of Milk Cows

Milk cows are generally found throughout the United States (Map 6). In the case of fluid milk, the production areas are often related to population centers while in the case of the less perishable manufactured dairy products processing plants are often located in areas where milk production has a comparative advantage. The upper Midwest and Northeastern areas lead in the number of cows on farms. Of the States with over 500 thousand head of cows on farms on June 1, 1969, Minnesota, Wisconsin, and Iowa, all in the Midwest, had a combined total of 3.4 million head, New York and Pennsylvania in the Northeastern area had a total of 1.75 million head, and California in the West had 0.8 million head.

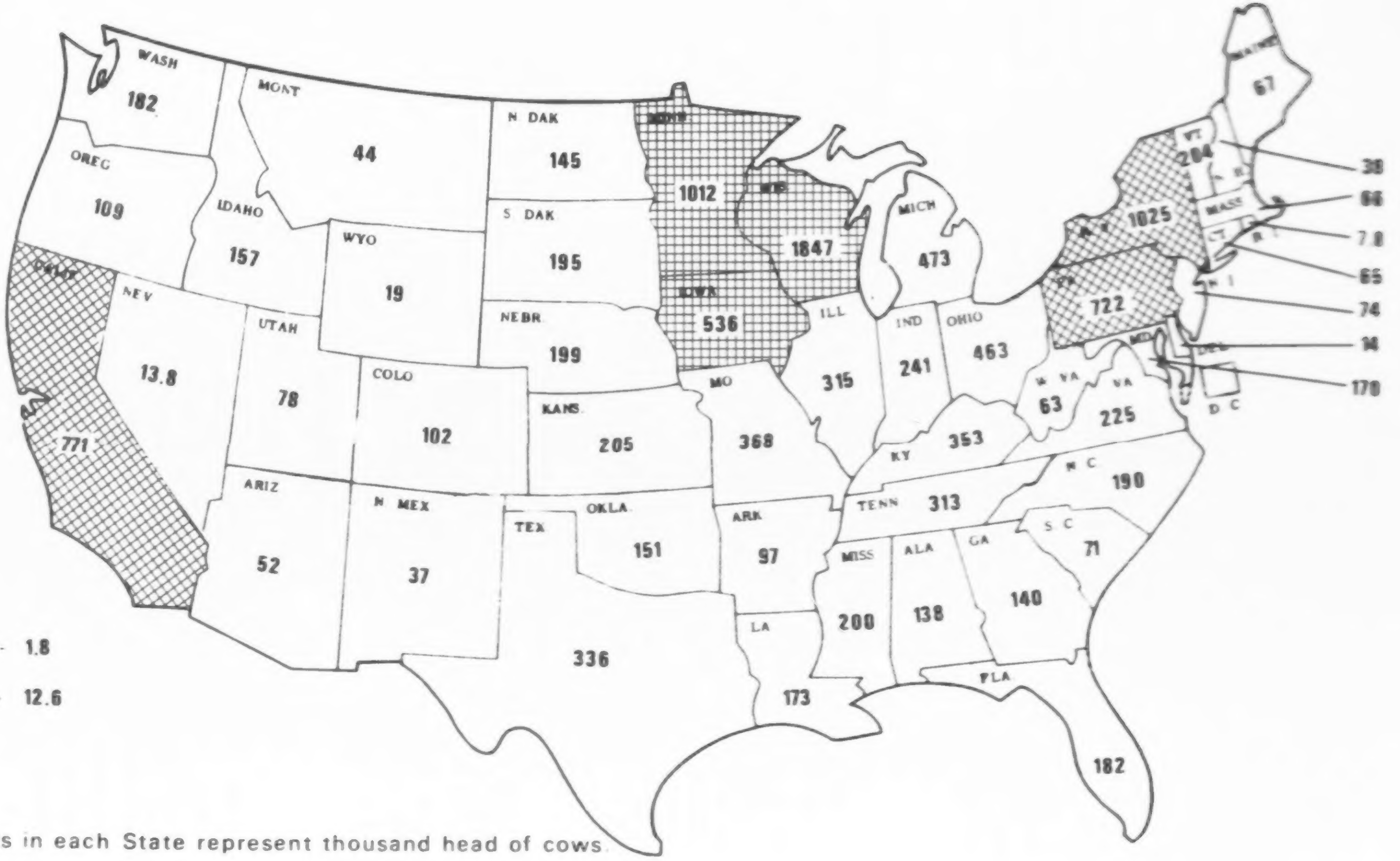
The cow numbers shown here only serve to indicate major concentrations of cows which, in turn, can serve as an indicator of areas where significant potential water pollution may exist. The actual pollution resulting from individual enterprises is, however, highly dependent upon the manure handling and disposal systems used by the enterprise, the climate, and the proximity of the enterprise or its disposal area to a watercourse.

Common Control Methods

A few of the water pollution control practices now in use include lagoons, covered operations with mechanical cleaning and disposal, some liquid manure handling systems, runoff diversion, and flush water containment with irrigation disposal. These measures vary as to applicability, cost, and effectiveness at the present time. However, ongoing research in the areas of biological treatment of animal wastes, land disposal problems and criteria, water recycling, and production technology should provide the basis for assessing the effectiveness of these and other control methods and the applicability of the methods

Map 6

Number of Milk Cows on Farms, by States, June 1969.


WASH 182
MONT 44
N DAK 145
MINN
1012
WIS
1847
MICH 473
MAINE 67
VT 204
N H
MASS
R I
CT
N Y 1025
PA 722
N J
DEL
MD
D C
38
66
7.8
65
74
14
170
OREG 109
IDAHO 157
WYO 19
S DAK 195
IOWA 536
NEBR 199
CALIF 771
NEV 13.8
UTAH 78
COLO 102
KANS 205
MO 368
ILL 315
IND 241
OHIO 463
W VA 63
VA 225
KY 353
N C 190
TENN 313
S C 71
ARIZ 52
N MEX 37
TEX 336
OKLA 151
ARK 97
MISS 200
ALA 138
GA 140
LA 173
FLA 182

Alaska - 1.8

Hawaii - 12.6

Numbers in each State represent thousand head of cows.

Shaded areas indicate States with over 500 thousand head.

under varying conditions. The knowledge of unit costs and applicability of control measures under various circumstances can then be combined with information on size and location of dairy farms to arrive at an estimate of the cost of controlling water pollution from dairy farms.

POULTRY

Poultry operations can generally be considered as falling into one of three major categories: broilers and layers, ducks, or turkeys. The volume of ducks and turkeys raised annually is not comparable with the volume of broilers and layers but their unique rearing arrangements set them apart as probable sources of significant water pollution on a limited basis.

Broilers and Layers

In providing a general overview of the animal wastes potential for water pollution, broilers and layers may be discussed in the same section because of the similarity of their wastes production and handling problems. A few of the wastes handling methods utilized by the broiler and layer industries have been previously discussed in the Regular Dischargers and Intermittent Dischargers sections of this report.

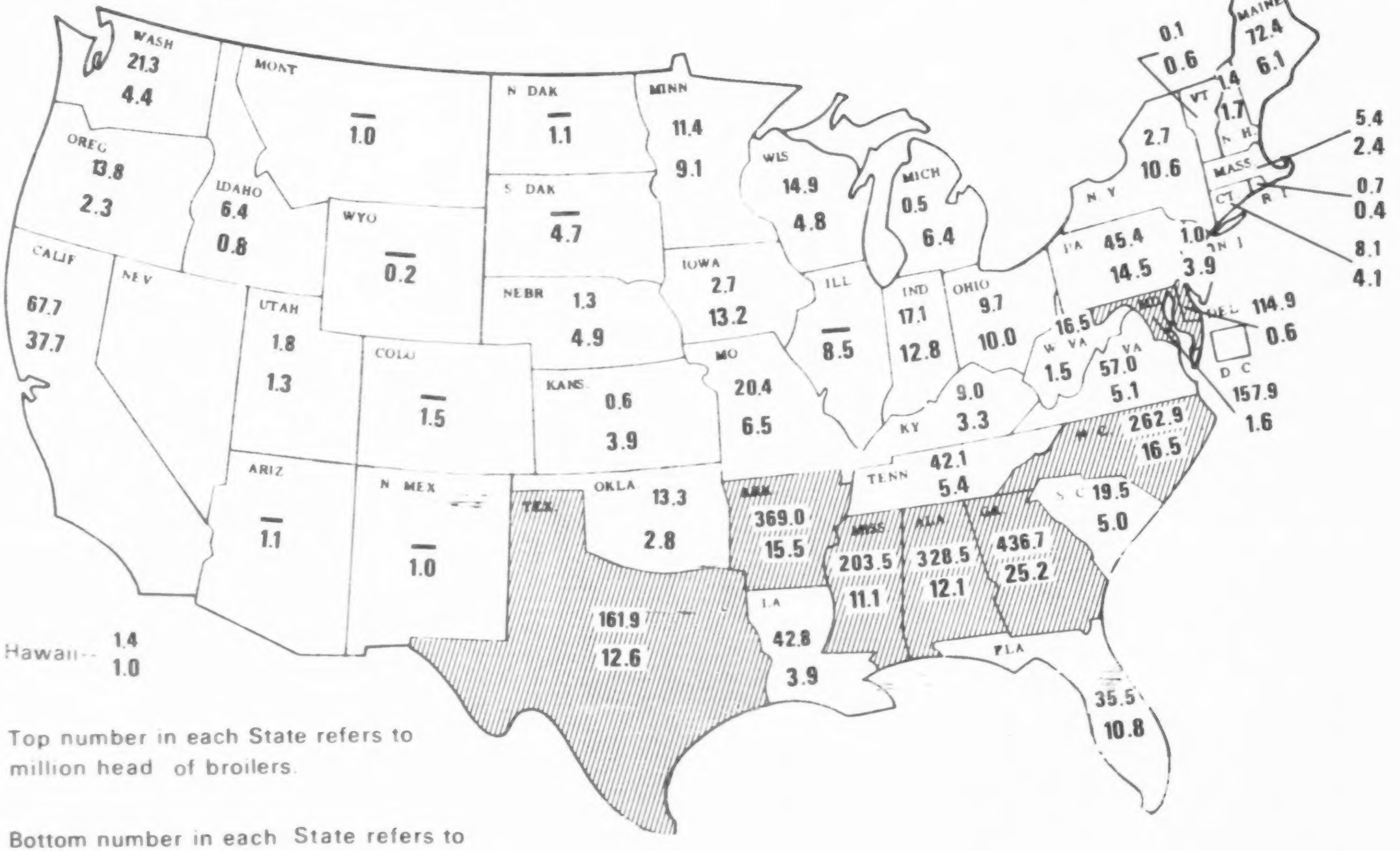
Regular dischargers are a source of major concern because of the frequency of their discharges. On the other hand, intermittent dischargers may appear to be less serious threats because of the lower frequency of discharges. However, taken as a unit throughout the Nation, intermittent dischargers pose a serious potential for water pollution. The nature of intermittent dischargers means that the enterprises will at one time or another be guilty of occasional discharges resulting in water pollution. For example, spreading wastes too near a watercourse or underdesigning a treatment or detention facility can result in intermittent discharges.

Location of Broiler Production

Commercial broiler production is presently concentrated in the south central and southeastern part of the United States (Map 7). In 1968, about 2.6 billion head of commercial broilers were produced in 42 States. Georgia, Arkansas, Alabama, North Carolina, and Mississippi were the leading States with a combined broiler production total of 1.6 billion birds in 1968. It is, therefore, readily apparent that broilers have a significant regional water pollution potential. However, despite this regional concentration, the numbers of broilers raised in the other areas shown on Map 6 indicate the necessity of studying the water pollution potential from broiler enterprises on a broad geographic base.

Map 7

Location and Number of Commercial Broilers Produced in 1968, and of Layers on Hand During October 1969.


WASH 21.3 4.4
OREG 13.8 2.3
CALIF 67.7 37.7
MONT 1.0
IDAHO 6.4 0.8
NEV
WYO 0.2
UTAH 1.8 1.3
COLO 1.5
ARIZ 1.1
N MEX 1.0
N DAK 1.1
S DAK 4.7
NEBR 1.3 4.9
KANS 0.6 3.9
OKLA 13.3 2.8
TEX 161.9 12.6
MINN 11.4 9.1
IOWA 2.7 13.2
MO 20.4 6.5
ARK 369.0 15.5
LA 42.8 3.9
WIS 14.9 4.8
ILL 8.5
MICH 0.5 6.4
IND 17.1 12.8
OHIO 9.7 10.0
KY 9.0 3.3
TENN 42.1 5.4
MISS 203.5 11.1
ALA 328.5 12.1
GA 436.7 25.2
FLA 35.5 10.8
S C 19.5 5.0
N C 262.9 16.5
VA 57.0 5.1
W VA 1.5 16.5
MD 157.9 1.6
DEL 114.9 0.6
D C
PA 45.4 14.5
N J 1.0 3.9
N Y 2.7 10.6
VT 0.1 0.6
N H 1.4 1.7
MAINE 72.4 6.1
MASS 5.4 2.4
R I 0.7 0.4
CT 8.1 4.1
Hawaii-- 1.4 1.0

Top number in each State refers to million head of broilers.

Bottom number in each State refers to million head of layers.

▨ Indicates States producing over 100 million broilers in 1968

Location of Layers

Layers, like broilers, have a regional concentration but the regional differences are not as pronounced for the layers (Map 7). Leading States in the number of layers on hand during October 1969 were California, Georgia, North Carolina, and Arkansas with a combined total of 94.9 million birds out of the 315.3 million birds for all States. In addition to the layers are the potential layers on hand for replacement and flock growth. These potential layers might amount to an additional 20 percent to the layers on hand. Overall, when the broilers, layers and potential layers are viewed together, the general magnitude of potential pollution indicates a need for further investigation.

Ducks

Duck raising enterprises utilizing water flowing in a channel along the duck feeding areas which are staged by bird age have been previously described in this report. The two major problems readily ascribable to this flowing water system are: (1) wastes are dropped directly into the channel by the ducks, and (2) duck wastes are washed from the feeding areas into the channel by rainfall. Since the water flowing through the channel must ultimately be disposed of, any wastes or pollutants carried by this water are potential watercourse pollutants.

The problem of wastes washing into the channel can be handled by diversion of outside runoff water and covering of the feeding areas. On the other hand, wastes deposited directly into the channel cannot be prevented as long as the water is a necessary part of the rearing operation. Therefore, the carriage water must be rendered innocuous before discharge to a watercourse.

Duck farmers in the Moriches Bay area near Patchogue, New York along with the Federal and State governments have been developing measures for controlling pollution from duck wastes. Basic criteria for treatment of the duck wastes were set at 85 percent removal of BOD and suspended solids, disinfection of the wastes, and substantial removal of the phosphates. Experiments have shown that aerated lagoons and chlorination accomplish the first three objectives but are not fully satisfactory in removing phosphates. Additional research is being completed on phosphate removal techniques applicable to the lagoon situation and should be available in the near future.

Where adequate land is available, evidence indicates that long detention times in an extensive lagoon system can also accomplish the objectives of disinfection and 85 percent removal of BOD and suspended solids. Use of lagoons without added aeration reduces the operation costs of the system but increases the investment in land and lagoons.

A third possibility for meeting the four standards is land disposal of the waste effluent through a land irrigation system. Such a system may be acceptable if the application rates are geared to the crops, soils, and climatic conditions.

Turkeys

There is very little information presently available with regard to turkey raising and its pollutional effect on watercourses. However, the rearing of turkeys takes place in confined outdoor areas quite similar to beef feedlots. Therefore, turkey feeding enterprises are subject to the same climatic effects as feedlots and should be studied to determine if they are sources of water pollution.

Turkey raising takes place across a wide range of climatic conditions as evidenced by the fact that the two leading turkey producing States are Minnesota and California (Map 8). Other heavy turkey producing areas tend to cluster around the Midwest and extend into the south central part of the United States.

Since the wastes from turkey enterprises tend to be subject to runoff, the turkey operations should be investigated to determine if they are indeed sources of water pollution. If it is determined that the wastes do cause water pollution, the control measures used for feedlots (e.g., water diversion, detention, covering, etc.) along with other poultry wastes control measures should be analyzed to determine their applicability to the turkey enterprises.

SWINE

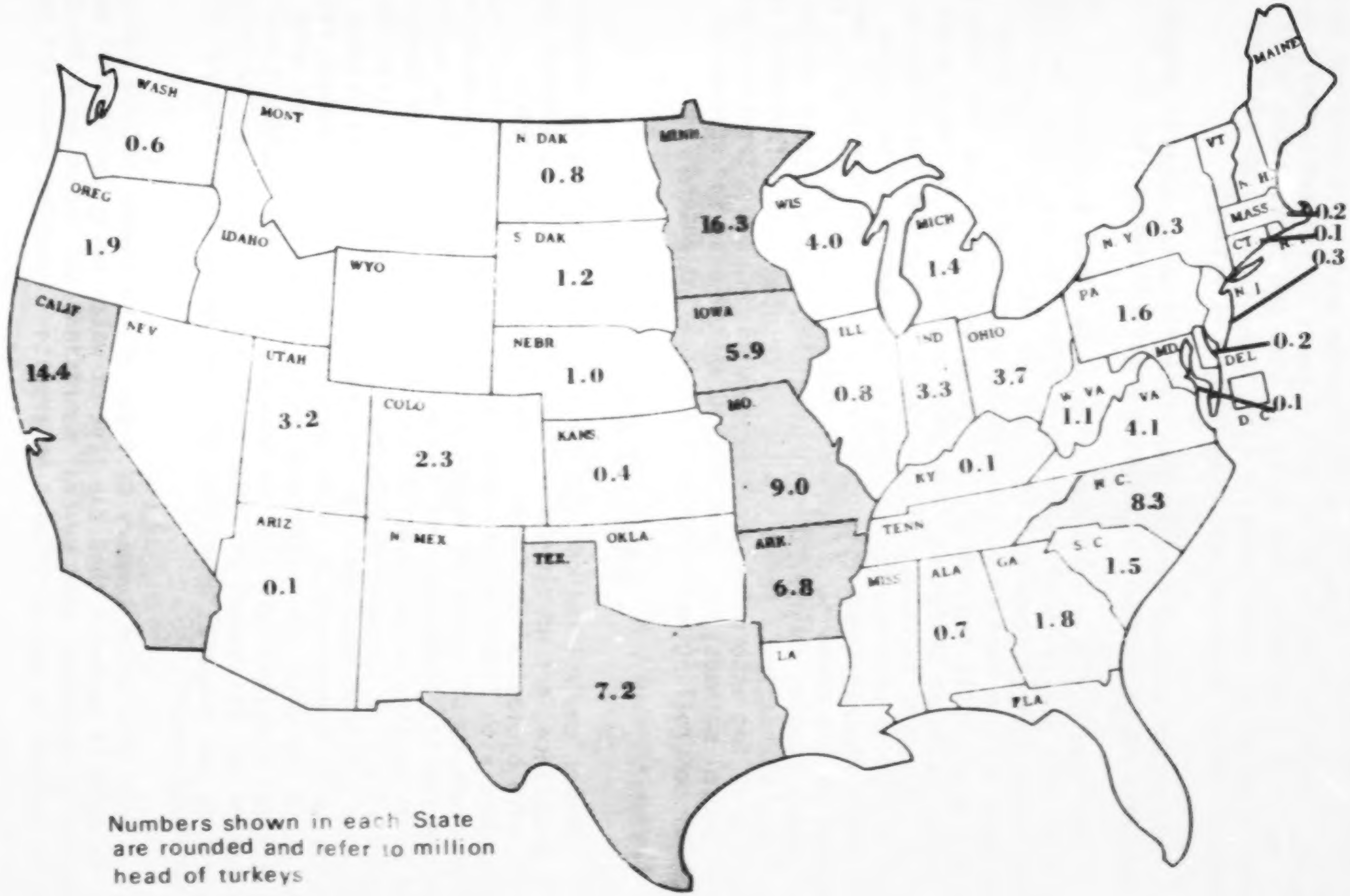
An earlier section dealing with the general aspects of animal wastes as they relate to water pollution discusses swine wastes and proposes that, for purposes of water pollution control analysis, the swine waste problem be divided into three components: finishing, farrowing, and farrowing-finishing. These earlier sections also point out that swine operations are readily adaptable to water flushing systems and that water flushing is often desirable from the enterprise's standpoint. As a result, many swine operations fall into the regular discharger category and have a high potential for water pollution. Other swine operations may utilize outdoor farrowing and finishing areas which tend to be similar to feedlots in runoff potential and fall in the intermittent to never categories.

Location of Swine Enterprises

The number of hogs on farms by States on January 1, 1969, is an indicator of the concentrations of hog enterprises and, consequently, an indicator of areas of potential water pollution from swine enterprises. Although these inventory numbers are helpful in indicating

Map 8

Location and Number of Turkeys Raised in 1968.


WASH
0.6
OREG
1.9
CALIF
14.4
IDAHO
NEV
MONT
WYO
UTAH
3.2
ARIZ
0.1
COLO
2.3
N MEX
N DAK
0.8
S DAK
1.2
NEBR
1.0
KANS
0.4
OKLA
TEX.
7.2
MINN.
16.3
IOWA
5.9
MO.
9.0
ARK.
6.8
LA
WIS
4.0
ILL
0.8
MICH
1.4
IND
3.3
OHIO
3.7
KY
0.1
TENN
MISS
ALA
0.7
GA
1.8
FLA
S C
1.5
N C
8.3
VA
4.1
W VA
1.1
PA
1.6
N Y
0.3
VT
N H
MAINE
MASS
0.2
CT
0.1
R I
0.3
N J
DEL
0.2
MD
D C
0.1

Numbers shown in each State are rounded and refer to million head of turkeys

Shaded areas indicate States producing over five million birds in 1968.

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major potential problem areas, they provide very little help in assessing actual pollution from swine enterprises. Total wastes produced by these hogs could be estimated using average wastes produced per animal figures. However, the value of such figures is limited because they only apply to a certain given point in time and because the total wastes produced by swine probably have very little to do with the amount of actual water pollution occurring at present.

The major swine producing and finishing areas cluster around the Midwest and reach into the southeastern United States (Map 9).

The leading State in number of hogs on farms on January 1, 1969, was Iowa with nearly 15 million head. Other leading States include Illinois with about seven million head and Indiana and Missouri with over four million head each. Outside of the midwestern and southeastern areas total hog numbers are relatively small and the likelihood of extensive water pollution from swine enterprises in these areas is low. However, there may still be many enterprises contributing their wastes to watercourses and the maximum extent of pollution from these contributions is dependent, in part, upon the local concentrations of hog numbers. Of course, this is true for all of the States and future studies should pinpoint local hog concentrations within the State boundaries. These locations, coupled with information as to the type of hog enterprise, weather conditions, and alternative pollution control methods, may then be used as the base for estimating costs of controlling water pollution from swine enterprises.

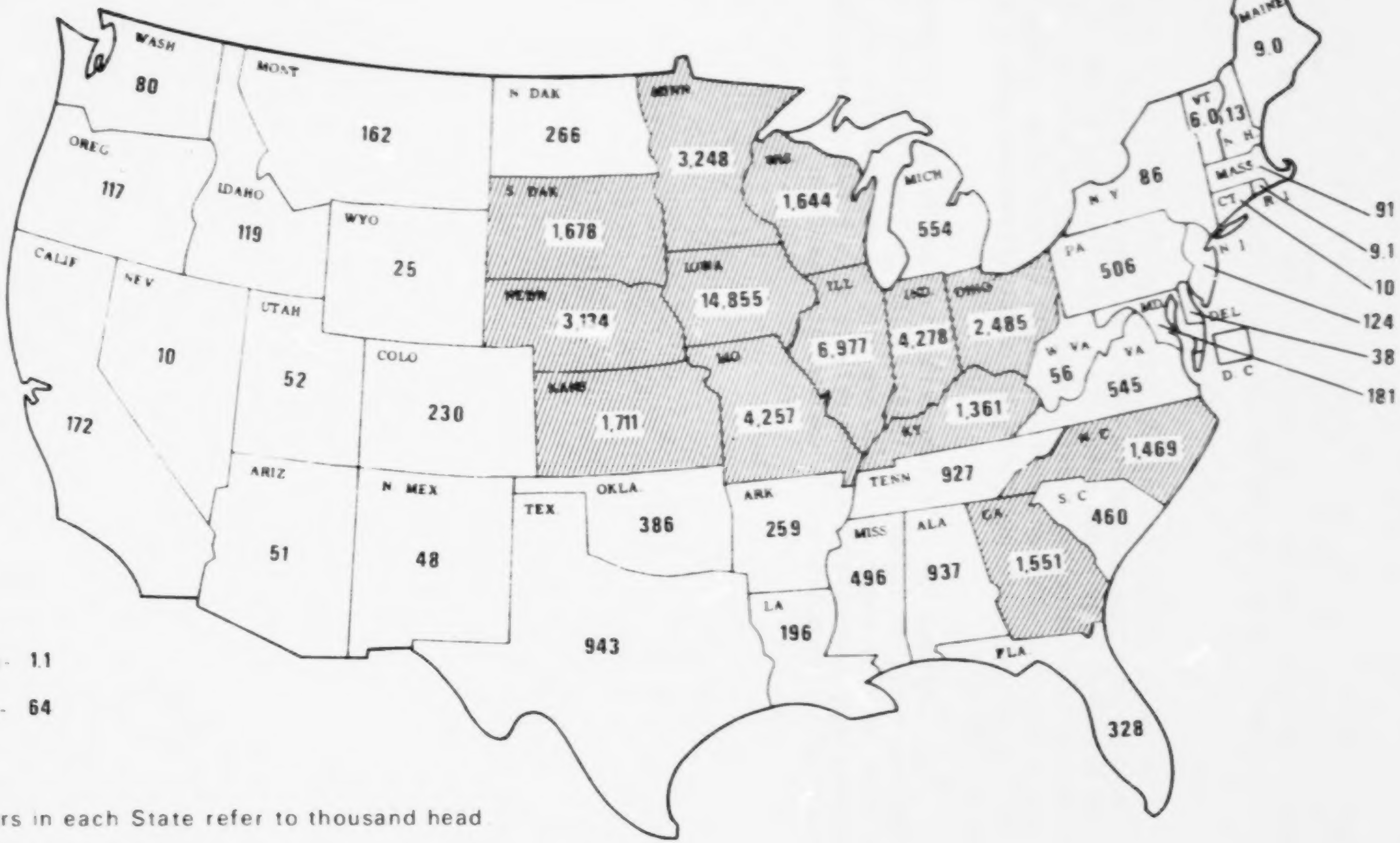
Common Control Methods

Common control methods, of varying costs, degrees of effectiveness and acceptance, are now in use. These include lagoons, covered operations with biological treatment in oxidation ditches, covered operations with liquid manure handling systems, and operations located to preclude runoff reaching watercourses. Each of these methods has its own special advantages and disadvantages in terms of the enterprise and as it relates to water pollution control. Lagoons, for example, may be effective in reducing biological loadings but do little for color or nutrient loadings. On the other hand, oxidation ditches can be virtually closed systems eliminating water quality problems but the operation costs are relatively high. Covered operations with mechanical cleaning can have low monetary costs for equipment and operation but the amount of labor required may limit the size of the operation and disposal practices must be limited to prevent pollution from field runoff.

From this brief summary of a few of the common control methods it is readily apparent that the type of water pollution control method adopted is dependent upon several conditions and varies with the conditions present in any particular enterprise. However, there are enough

Map 9

Number and Location of Hogs on Farms January 1,1969


WASH 80
OREG 117
CALIF 172
IDAHO 119
NEV 10
MONT 162
WYO 25
UTAH 52
ARIZ 51
COLO 230
N MEX 48
N DAK 266
S DAK 1,678
NEBR 3,134
KANS 1,711
OKLA 386
TEX 943
MINN 3,248
IOWA 14,855
MO 4,257
ARK 259
LA 196
WIS 1,644
ILL 6,977
MICH 554
IND 4,278
OHIO 2,485
KY 1,361
TENN 927
MISS 496
ALA 937
GA 1,551
FLA 328
S C 460
N C 1,469
VA 545
W VA 56
PA 506
N Y 86
VT 6.0
N H 13
MAINE 9.0
MASS
R I
CT
N J
DEL
MD
D C
91
9.1
10
124
38
181

Alaska- 1.1

Hawaii- 64

Numbers in each State refer to thousand head

Shaded area indicates States with over one million head common characteristics among groups of enterprises to permit aggregation of numbers of hogs and enterprises, and of control methods within these groups so that total pollution control costs can be estimated once future studies provide the necessary base data.

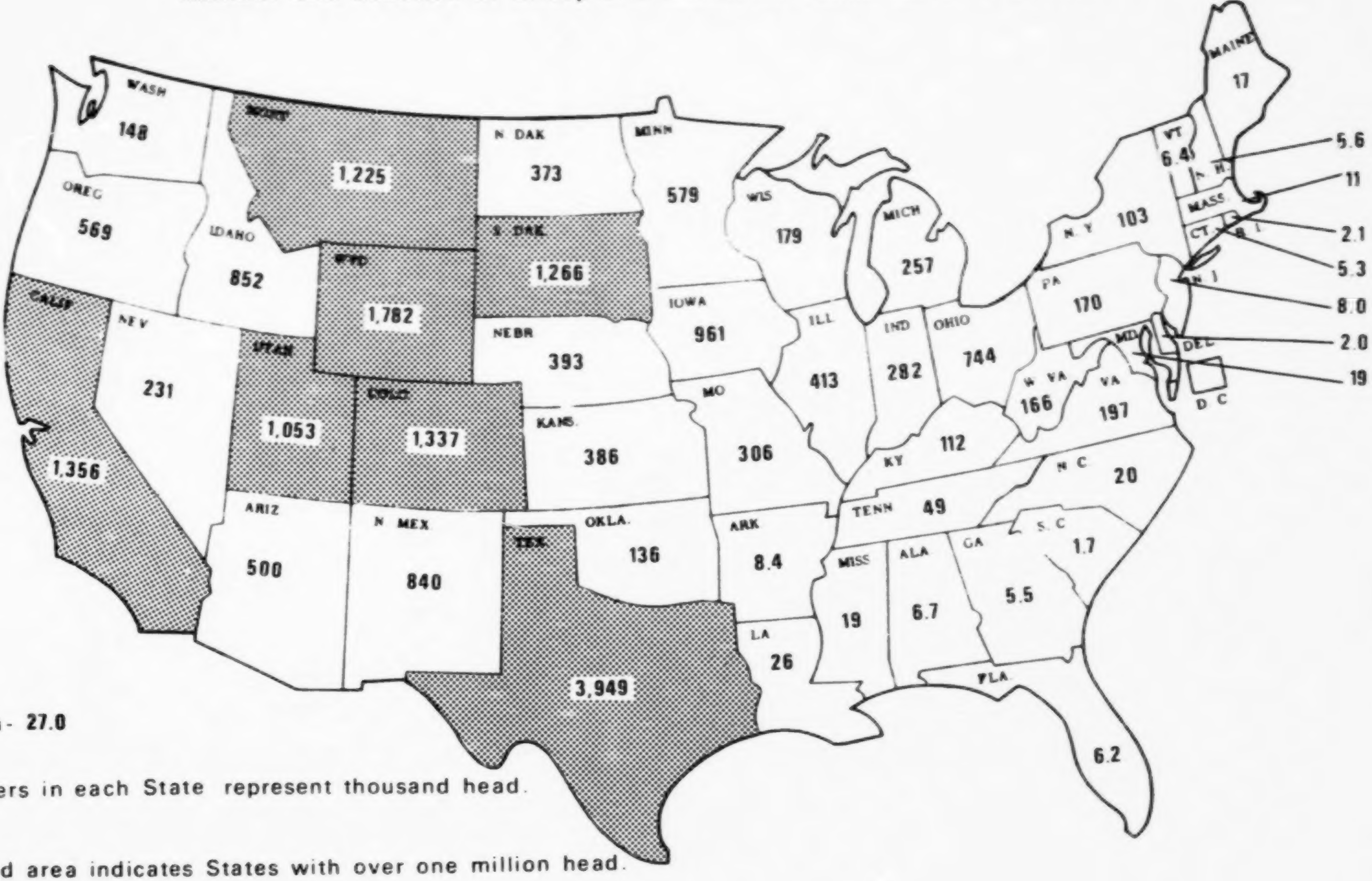
SHEEP

There is little information presently available that can be used to measure the impact of sheep wastes on water pollution. The range type nature of many sheep enterprises probably places them in the seldom to never discharger categories discussed in earlier sections of this report. However, there may well be many cases of sheep wastes contributing to water pollution and these situations must ultimately be controlled.

Map 10 shows the relative concentrations by State of sheep and lambs on farms on January 1, 1969. Although the States with over one million head of sheep and lambs are singled out to reveal the areas of heaviest concentrations, the relationship between these areas and water pollution potential is unknown at this time.

Map 10

Number and Location of Sheep and Lambs on Farms January 1,1969


WASH
148
OREG
569
IDAHO
852
MONT
1,225
WYO
1,782
N DAK
373
S DAK
1,266
CALIF
1,356
NEV
231
UTAH
1,053
COLO
1,337
NEBR
393
KANS
386
ARIZ
500
N MEX
840
TEX
3,949
OKLA
136
MINN
579
IOWA
961
MO
306
ARK
8.4
LA
26
WIS
179
ILL
413
MICH
257
IND
282
OHIO
744
KY
112
TENN
49
MISS
19
ALA
6.7
GA
5.5
FLA
6.2
S C
1.7
N C
20
VA
197
W VA
166
MD
PA
170
N Y
103
VT
6.4
N H
MAINE
17
MASS
CT
R I
N J
DEL
D C
5.6
11
2.1
5.3
8.0
2.0
19

Alaska - 27.0

Numbers in each State represent thousand head.

Shaded area indicates States with over one million head.

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